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(71) Applicant: **DENSO CORPORATION**
Aichi 448-8661 (JP)

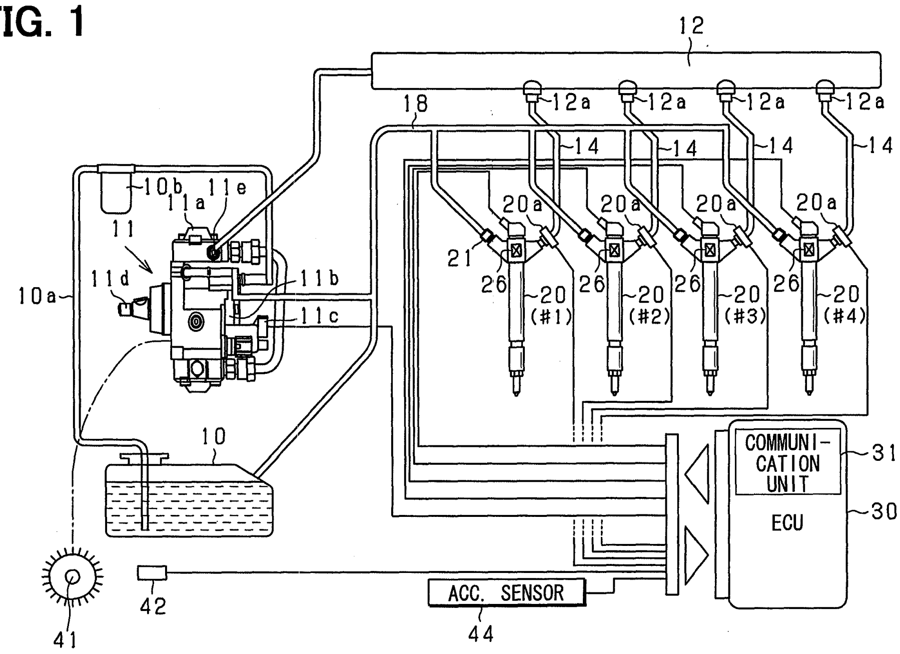
(72) Inventors:
- **NAKATA, Kenichiro**
Kariya-city Aichi 448-8661 (JP)
- **ISHIZUKA, Koji**
Kariya-city Aichi 448-8661 (JP)

(74) Representative: **TBK-Patent**
Bavariaring 4-6
80336 München (DE)

(54) **Fuel injection device, fuel injection system, and method for determining malfunction of the same**

(57) A fuel injection device includes a fuel injection valve (20) for injecting fuel, which is distributed from a pressure-accumulation vessel (12). A pressure sensor (20a) is located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a nozzle hole (20f) of the fuel injection valve (20). The pressure sensor (20a) is located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12) and configured to detect pressure of fuel. The fuel injection device further includes a storage unit (26) for storing individual difference information, which indicates an injection characteristic of the fuel injection valve (20). The injection characteristic is obtained by an examination. The individual difference information indicates a relationship between an injection state when the fuel injection valve (20) performs fuel injection and a fluctuation in detected pressure of the pressure sensor (20a). The fluctuation is attributed to the fuel injection.

FIG. 1



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Description

[0001] The present invention relates to a fuel injection device having a fuel injection valve for injecting fuel, which is distributed from a pressure-accumulation vessel. The present invention further relates to a fuel injection system having the fuel injection device. The present invention further relates to a method for determining malfunction in the fuel injection device.

[0002] Conventionally, a common-rail fuel injection device includes a common rail as a pressure-accumulation vessel, which is configured to accumulate fuel at high pressure. The common rail is further configured to distribute the high-pressure fuel to fuel injection valves for injecting the distributed fuel respectively to cylinders of an internal combustion engine. Such a conventional common-rail fuel injection device in JP-A-2006-200378 includes a pressure sensor as a rail pressure sensor. The pressure sensor is mounted to the common rail for detecting pressure of fuel accumulated in the common rail. The common-rail fuel injection device is configured to control various devices such as a fuel pump for supplying fuel to the common rail based on a detection result of the pressure sensor.

[0003] The fuel injection device in JP-A-2006-200378 controls an injection quantity Q by controlling an opening period Tq of the fuel injection valve. Even in fuel injection valves of the same type, each fuel injection valve has a specific relationship between the opening period and the injection quantity, and the specific relationship has an individual difference. Therefore, the specific relationship as an injection characteristic (Tq-Q characteristic) is examined for each fuel injection valve before factory shipment thereof. The injection characteristic, which is obtained through the examination, is encoded to generate a QR Code (registered trademark), which indicates individual difference information. The QR Code is adhered to the fuel injection valve.

[0004] The QR Code, which indicates the individual difference information, is read using a scanner device. Thereafter, the individual difference information is stored in an engine ECU, which controls an operating condition of an engine. After the factory shipment of the fuel injection valve, the fuel injection valve is mounted to an engine. Thus, the engine ECU of the engine manipulates the opening period Tq based on the stored individual difference information, thereby controlling the injection quantity Q of the fuel injection valve.

[0005] However, in recent years, it is required to further control various kinds of injection states, in addition to controlling the injection quantity Q in one opening of in the fuel injection valve, which is mounted to the engine. The various kinds of injection states may include an actual injection start point, a maximum injection rate reach point, and the like in each injection. That is, even when the injection quantity Q is the same, if an injection state such as an actual injection start point and a maximum injection rate reach point is changed, the combustion state of the engine is changed. As a result, output torque of the engine and the state of exhaust air are changed.

[0006] In particular, in a fuel injection device for performing a multi-stage injection in a diesel engine, it is required to control the injection state, such as actual injection start point and the maximum injection rate reach point, other than the injection quantity Q so as to control multiple fuel injections in one burning cycle.

[0007] On the contrary, in the fuel injection device according to JP-A-2006-200378, only the Tq-Q characteristic is obtained by conducting the examination, and the Tq-Q characteristic is stored as the individual difference information of the fuel injection valve. Therefore, injection states other than the injection quantity Q cannot be obtained as the individual difference. Thus, it is difficult to control the injection states other than injection quantity Q with high accuracy.

[0008] In view of the foregoing and other problems, it is an object of the present invention to produce a fuel injection device, which is capable of controlling an injection state of a fuel injection valve with high accuracy. It is another object to produce a fuel injection system having the fuel injection device. It is another object of the present invention to produce a method for determining a malfunction in a fuel injection device, the fuel injection device being capable of controlling an injection state thereof at high accuracy.

[0009] According to one aspect of the present invention, a fuel injection device configured to be supplied with fuel from a pressure-accumulation vessel, the fuel injection device comprises a fuel injection valve for injecting fuel, which is distributed from the pressure-accumulation vessel. The fuel injection device further comprises a pressure sensor located in a fuel passage, which extends from the pressure-accumulation vessel to a nozzle hole of the fuel injection valve, the pressure sensor being located closer to the nozzle hole than the pressure-accumulation vessel and configured to detect pressure of fuel. The fuel injection device further comprises a storage unit for storing individual difference information, which indicates an injection characteristic of the fuel injection valve, the injection characteristic being obtained by an examination. The individual difference information indicates a relationship between an injection state when the fuel injection valve performs fuel injection and a fluctuation in detected pressure of the pressure sensor, the fluctuation being attributed to the fuel injection.

[0010] According to another aspect of the present invention, a fuel injection device configured to be supplied with fuel from a pressure-accumulation vessel, the fuel injection device comprises a fuel injection valve for injecting fuel, which is distributed from the pressure-accumulation vessel. The fuel injection device further comprises a pressure sensor located in a fuel passage, which extends from the pressure-accumulation vessel to a nozzle hole of the fuel injection valve, the pressure sensor being located closer to the nozzle hole than the pressure-accumulation vessel and configured to detect pressure of fuel. The fuel injection device further comprises a storage unit for storing individual difference information, which indicates an injection characteristic of the fuel injection valve, the injection characteristic being obtained by an examination. The individual difference information indicates an error of an object fluctuation mode of the fuel injection valve and pressure sensor as examined objects with respect to a reference fluctuation mode of a master sensor and a master fuel injection valve. Each of the object fluctuation mode and the reference fluctuation mode represents a fluctuation in detected pressure subsequent to an output of an injection instruction signal. The object fluctuation mode is obtained by an examination of the fuel injection valve and pressure sensor as the examined objects, which are respectively different from the master fuel injection valve and the master sensor.

[0011] According to another aspect of the present invention, a method for determining a malfunction caused in a fuel injection device, the fuel injection device including a fuel injection valve, which is configured to inject fuel distributed from a pressure-accumulation vessel, and a pressure sensor, which is located in a fuel passage extending from the pressure-accumulation vessel to a nozzle hole for detecting pressure of fuel, the pressure sensor being located closer to the nozzle hole than the pressure-accumulation vessel, the method comprises first-measuring a fluctuation in detected pressure mode of the pressure sensor, the fluctuation appearing after an output of an injection instruction signal. The method further comprises second-measuring an object fluctuation mode by conducting an examination for the fuel injection valve and pressure sensor as examined objects of the malfunction. The method further comprises determining that the examined objects malfunction when an error of the object fluctuation mode with respect to a reference fluctuation mode as a reference is larger than a threshold.

[0012] According to another aspect of the present invention, a method for determining a malfunction caused in a fuel injection device, the fuel injection device including a fuel injection valve, which is configured to inject fuel distributed from a pressure-accumulation vessel, and a pressure sensor, which is located in a fuel passage extending from the pressure-accumulation vessel to a nozzle hole for detecting pressure of fuel, the pressure sensor being located closer to the nozzle hole than the pressure-accumulation vessel, the method comprises first-measuring a reference fluctuation mode by conducting an examination for a master sensor and a master fuel injection valve. The method further comprises second-measuring an object fluctuation mode by conducting an examination for the fuel injection valve and pressure sensor as examined objects of the malfunction. Each of the reference fluctuation mode and the object fluctuation mode represents a fluctuation in detected pressure subsequent to an output of an injection instruction signal. The master fuel injection valve and the master sensor being respectively different from the fuel injection valve and pressure sensor. The method further comprises determining that at least one of the examined objects malfunctions when a deviation between the object fluctuation mode and the reference fluctuation mode is larger than a threshold.

[0013] The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. 1 is a schematic diagram showing an outline of a fuel injection device and an engine control system according to an embodiment;
FIG. 2 is a schematic sectional view showing an internal structure of a fuel injection valve employed in the engine control system;
FIG. 3 is a flow chart showing an injection control according to the first embodiment;
FIG. 4 is a schematic diagram showing a system for examination of an injection characteristic according to the first embodiment;
FIG. 5 is a timing chart showing the injection characteristic according to the first embodiment;
FIG. 6 is a flowchart showing a procedure of a calculation process for individual difference information and a writing process to an IC memory;
FIG. 7 is a flowchart showing a procedure of a calculation process for individual difference information and a writing process to an IC memory;
FIG. 8 is a timing chart showing the injection characteristic according to the first embodiment;
FIG. 9 is a timing chart showing the injection characteristic according to the first embodiment;
FIG. 10 is a timing chart showing the injection characteristic according to the first embodiment;
FIG. 11 is a timing chart showing the injection characteristic according to the first embodiment;
FIG. 12 is a timing chart showing the injection characteristic according to the first embodiment;
FIG. 13 is a timing chart showing a reference characteristic and error with respect to a master device according to a second embodiment;
FIG. 14 is a flowchart showing a procedure for determining a malfunction caused in a fuel injection device as an examined object according to a second embodiment; and
FIG. 15 is a flowchart showing a procedure for determining a malfunction caused in a fuel injection device as an examined object according to a third embodiment.

(First Embodiment)

[0014] A fuel injection device according to the present embodiment is mounted to, for example, a common-rail fuel injection system for an internal combustion engine for an automobile. For example, the present fuel injection device is used for directly injecting high-pressure fuel to a combustion chamber in a cylinder of a diesel engine. The high-pressure fuel is, for example, light oil, which is at injection pressure more than 100MPa.

[0015] First, the common-rail fuel injection system as an in-vehicle engine system according to the present embodiment is described with reference to FIG. 1. In the present embodiment, the engine is, for example, a multi-cylinder engine such as an inline four-cylinder engine. Specifically, the engine may be a four-stroke reciprocal diesel engine. In the present engine, an electromagnetic pickup as a cylinder-detection sensor is provided to a camshaft of an intake valve and an exhaust valve so as to successively determine an object cylinder at that time. Each of four cylinders #1 to #4 repeats four-stroke combustion cycles, each including an intake stroke, a compression stroke, a combustion stroke, and an exhaust stroke, at 720 degree CA (crank angle). In detail, the #1, #3, #4, #2 cylinders perform the four-stroke combustion cycle in this order at 180-degree-CA shift relative to each other. In FIG. 1, injectors 20 as fuel injection valves are respectively assigned to the cylinders #1, #2, #3, #4 from the side of a fuel tank 10.

[0016] As shown in FIG. 1, the present fuel injection system includes an electronic control unit (ECU) 30, which is configured to input detection signals, which are outputted from various sensors, and control components of a fuel supply system in accordance with the detection signals. The ECU30 controls an electric current, which is supplied to a suction control valve 11c, thereby controlling an amount of fuel discharged from a fuel pump 11. The ECU30 performs a feedback control such as PID control to regulate fuel pressure in a common rail 12 as a pressure-accumulation vessel at target fuel pressure. The pressure in the common rail 12 is detected using a pressure sensor 20a. The ECU30 controls an amount of fuel injected into a specific cylinder of the engine based on the fuel pressure, thereby controlling rotation speed and torque of an output shaft of the engine.

[0017] The fuel tank 10, the fuel pump 11, the common rail 12, and the injectors 20 are arranged in this order from the upstream in the fuel supply system. The fuel tank 10 is connected with the fuel pump 11 through a fuel filter 10b and a pipe 10a.

[0018] The fuel tank 10 as a vessel is for storing fuel such as light oil for the engine. The fuel pump 11 includes a high-pressure pump 11a and a low-pressure pump 11b. The low-pressure pump 11 b is configured to pump fuel from the fuel tank 10, and the high-pressure pump 11a is configured to further pressurize the fuel pumped from the low-pressure pump 11 b. A suction control valve (SCV) 11c is provided in an inlet of the fuel pump 11 to control an amount of fuel fed to the high-pressure pump 11a. In the present structure, the suction control valve 11c controls an amount of fuel discharged from the fuel pump 11. The suction control valve 11c is, for example, a normally-on regulating valve, which opens when being de-energized. In the present structure, an amount of fuel discharged from the fuel pump 11 can be regulated by controlling a drive current supplied to the suction control valve 11c so as to manipulate a valve-opening area of the suction control valve 11c.

[0019] The low-pressure pump 11 b of the fuel pump 11 is, for example a trochoid feed pump. The high-pressure pump 11a is, for example, a plunger pump, which is configured to feed fuel from compression chambers by axially moving plungers successively at predetermined intervals by using an eccentric cam (not shown). The plungers may include three plungers, for example. The pumps are driven by using a driving shaft 11d. The driving shaft 11 d is interlocked with a crankshaft 41, which is an output shaft of the engine. The driving shaft 11 d is configured to rotate at a ratio such as one-to-one or one-to-two with respect to one rotation of the crankshaft 41, for example. In the present structure, the low-pressure pump 11 b and the high-pressure pump 11a are driven by the output power of the engine.

[0020] The fuel pump 11 pumps fuel from the fuel tank 10 through the fuel filter 10b and press-feeds the pumped fuel to the common rail 12. The common rail 12 stores the fuel, which is fed from the fuel pump 11, at high pressure. The common rail 12 distributes the accumulated fuel to the injector 20 of each of the cylinders #1 to #4 through a high-pressure pipe 14, which is provided to each cylinder. Each of the injectors 20(#1) to 20(#4) has an exhaust port 21, which is connected with a pipe 18 for returning excessive fuel to the fuel tank 10. An orifice 12a as a pulsation reducing unit is provided to a connection between the common rail 12 and the high-pressure pipe 14 for attenuating pulsation in pressure of fuel, which flows from the common rail 12 into the high-pressure pipe 14.

[0021] FIG. 2 shows a detailed structure of the injector 20. The four injectors 20(#1) to 20(#4) substantially has the same structure, which is, for example, the structure shown in FIG. 2. Each injector 20 is a fuel injection valve, which is hydraulically actuated using fuel, which is drawn from the fuel tank 10 and to be burned in the engine. In the injector 20, driving power for fuel injection is transmitted via a hydraulic pressure chamber Cd as a control chamber. As shown in the FIG. 2, the injector 20 is configured as the normally-close fuel injection valve, which is in a closed state when being de-energized.

[0022] High-pressure fuel is supplied from the common rail 12, and the High-pressure fuel flows into a fuel inlet hole 22, which is provided in a housing 20e of the injector 20. The supplied high-pressure fuel partially flows into the hydraulic pressure chamber Cd, and remaining high-pressure fuel flows to nozzle holes 20f. The hydraulic pressure chamber Cd has a leak hole 24, which is opened and closed by a control valve 23. When the leak hole 24 is opened by lifting the control valve 23, fuel is returned from the hydraulic pressure chamber Cd to the fuel tank 10 through the leak hole 24 and the exhaust port 21.

[0023] In the fuel injection of the injector 20, the control valve 23 is operated according to the energization and de-energization of a solenoid 20b, which is a two-way solenoid valve, whereby the control valve 23 controls leakage of fuel from the hydraulic pressure chamber Cd. Thus, the control valve 23 controls pressure in the hydraulic pressure chamber Cd. Here, the pressure in the hydraulic pressure chamber Cd is equivalent to back-pressure applied to a needle valve 20c. Thus, the needle valve 20c reciprocates upward and downward inside the housing 20e according to the change in pressure in the hydraulic pressure chamber Cd, while being applied with biasing force of a coil spring 20d. In the present operation, a fuel passage 25, which extends to the nozzle holes 20f, is opened and closed midway therethrough. Specifically, the fuel passage 25 has a tapered seat surface, and the needle valve 20c is seated to and lifted from the tapered seat surface in accordance with the reciprocation of the needle valve 20c, whereby the needle valve 20c communicates and blockades the fuel passage 25. The number of the nozzle holes 20f may be arbitrary determined.

[0024] The needle valve 20c is, for example, on-off controlled. Specifically, the needle valve 20c has the two-way solenoid valve as the actuator, which is applied with a pulse signal as an energization signal. The pulse signal as an ON-OFF signal is transmitted from the ECU30 to energize and de-energize the solenoid valve. The needle valve 20c is lifted by turning on the pulse signal, thereby opening the nozzle holes 20f. The needle valve 20c is seated by turning off the pulse signal, thereby blockading the nozzle holes 20f.

[0025] The pressure in the hydraulic pressure chamber Cd is increased by supplying fuel from the common rail 12. On the other hand, the pressure in the hydraulic pressure chamber Cd is decreased by energizing the solenoid 20b to manipulate the control valve 23 so as to open the leak hole 24. In the present structure, fuel is returned from the hydraulic pressure chamber Cd to the fuel tank 10 through the pipe 18 (FIG. 1), which connects the injector 20 with the fuel tank 10. That is, the fuel pressure in the hydraulic pressure chamber Cd is controlled by manipulating the control valve 23, so that the needle valve 20c is operated for opening and closing the nozzle holes 20f.

[0026] In the present structure, the injector 20 includes the needle valve 20c, which is configured to open and close the injector 20 by opening and closing the fuel passage 25, which extends to the nozzle holes 20f, in conjunction with the predetermined axial reciprocation inside the housing 20e as the valve body. When the solenoid is de-energized, the needle valve 20c is displaced to a close side by being applied with the biasing force of the spring 20d, which is regularly exerted toward the close side. When the solenoid is energized, the needle valve 20c is displaced to an open side by being applied with the driving force against the biasing force of the spring 20d. The lift of the needle valve 20c when being energized is substantially symmetric with the lift of the needle valve 20c when being de-energized.

[0027] The injector 20 is provided with the pressure sensor 20a (FIG. 1) for detecting fuel pressure. Specifically, the fuel inlet hole 22 of the housing 20e is connected with the high-pressure pipe 14 via a jig 20j. The pressure sensor 20a is attached to the jig 20j. Here, in a stage where the injector 20 is shipped from a factory, the injector 20 is attached with the Jig 20j, the pressure sensor 20a, and an IC memory 26 (FIGS. 1, 4). The IC memory 26 is constructed of an integrated circuit.

[0028] Thus, the fuel pressure as inlet pressure in the fuel inlet hole 22 can be arbitrary detected by the pressure sensor 20a, which is mounted to the fuel inlet hole 22 of the injector 20. Specifically, a fluctuation pattern of the fuel pressure attributed to fuel injection of the injector 20, a fuel pressure level (stable pressure), fuel injection pressure, and the like can be detected in accordance with the output of the pressure sensor 20a.

[0029] The pressure sensor 20a is provided to each of the injectors 20(#1) to 20(#4). In the present structure, the fluctuation pattern of the fuel pressure attributed to specific fuel injection of the injector 20 can be accurately detected based on the output of the pressure sensor 20a.

[0030] In addition, various kinds of sensors for a vehicle control other than the above-mentioned sensors are provided in a vehicle such as a four-wheel automobile or a track (not shown). For example, a crank angle sensor 42 such as an electromagnetic pick up is provided to the outer periphery of the crankshaft 41, which is an output shaft of the engine. The crank angle sensor 42 is configured to detect the rotation angle and the rotation speed of the crankshaft 41, which corresponds to the engine rotation speed. The crank angle sensor 42 is configured to output a crank angle signal at predetermined intervals such as 30 degree-CA. An accelerator sensor 44 is provided to detect a manipulation, which corresponds to depression of an accelerator by a driver. The accelerator sensor 44 is configured to output an electric signal according to a state, which corresponds to the position of the accelerator.

[0031] The ECU 30 predominantly performs an engine control as a fuel injection device in the present system. The ECU 30 as an engine control ECU includes a generally-known microcomputer (not shown). The ECU 30 determines an operating state of the engine and an occupant's demand on the basis of the detection signals of the various sensors, thereby operating various actuators such as the suction control valve 11c and the injector 20 in response to the operating state and the occupant's demand. Thus, the ECU 30 performs various controls relating to the engine in optimal modes adaptively to the various conditions.

[0032] The microcomputer of the ECU30 includes a CPU as a main processing unit, which performs various kinds of operations, a RAM as a main memory, which stores temporarily data, an operation result, and the like, a ROM as a program memory, an EEPROM as a data storage, a backup RAM, and the like. The backup RAM is a memory, which is regularly supplied with electric power from a backup power supply such as an in-vehicle battery even when the main power supply of the ECU30 is terminated. Various programs and control data maps relating to the fuel injection are stored in advance in the ROM and various control data including the design data of the engine are stored in the data storage memory such as the EEPROM.

[0033] In the present embodiment, the ECU30 calculates demand torque, which is required to the crankshaft 41 as the output shaft, and fuel injection quantity for satisfying the demand torque, based on various kinds of sensor outputs as the detection signals, which are arbitrary inputted. In the present structure, the ECU 30 variably sets the fuel injection quantity of the injector 20, thereby controlling engine torque, which is generated through fuel combustion in the combustion chamber of each cylinder. Thus, the ECU 30 controls axial torque as output torque, which is actually outputted to the crankshaft 41, at the demand torque.

[0034] That is, the ECU30 calculates, for example, the fuel injection quantity according to the engine operation state and manipulation of the accelerator by the driver, and the like at the time. The ECU 30 outputs the injection control signal (drive quantity) to the injector 20 so as to direct to inject fuel correspondingly to the fuel injection quantity at a predetermined injection timing. In the present structure, the ECU 30 controls the output torque of the engine at the target torque based on the drive quantity such as an opening period of the injector 20. As generally known, in a diesel engine, an intake throttle valve (throttle valve), which is provided in an intake passage of the engine, is held at a substantially full open state in a steady operation so as to further draw fresh air and to reduce pumping loss. Therefore, the fuel injection quantity is mainly manipulated for controlling a combustion state at the time of the steady operation. In particular, a combustion control related to a torque adjustment is mainly performed at the time of the steady operation.

[0035] As follows, the fuel injection control according to the present embodiment is described with reference to FIG. 3. In this regard, the values of various parameters used in the processing shown in FIG. 3 are sequentially stored in the storage device, and are sequentially updated as needed. The storage device may be the RAM and the EEPROM mounted in the ECU 30, or the backup RAM. Basically, the series of processings in FIG. 3 is performed once per one burning cycle of for each cylinder of the engine. The processings in FIG. 3 is performed by executing the program stored in the ROM of the ECU30. That is, by executing the present program, fuel supply to all the cylinders excluding an inactive cylinder is performed in a one burning cycle.

[0036] In the series of the present processing shown in FIG. 3, at step S11, predetermined parameters are read. The predetermined parameters may include the engine speed, the fuel pressure, an accelerator manipulation of the driver, and the like at that time. The engine speed may be obtained based on an actual measurement of the crank angle sensor 42. The fuel pressure may be obtained based on an actual measurement of the pressure sensor 20a. The accelerator manipulation may be obtained from an actual measurement of the accelerator sensor 44.

[0037] At subsequent step S12, an injection pattern is set up based on the various parameters, which are read at step S11. The injection patterns are variably determined according to the demand torque of the crankshaft 41, which is equivalent to the engine load at that time. For example, in a single-stage injection, the injection quantity (injection period) of the single-stage injection is variably determined as the injection pattern. Alternatively, in a multi-stage injection, the total injection quantity (the total injection period) of injections, which contribute to the engine torque, is variably determined as the injection pattern. Thus, a command value as an instruction signal for the injector 20 is set up based on the injection pattern. In the present structure, a pilot injection, a pre-injection, an after-injection, a post-injection, and the like are suitably performed with main injection according to the condition of the vehicle and the like.

[0038] The present injection pattern is obtained based on a predetermined data map such as a data map for the injection control and a correction coefficient stored in the ROM, for example. The predetermined data map may be substituted to an equation. Specifically, for example, an optimal injection pattern (conformed value) may be beforehand obtained in an assumed range of the predetermined parameter (step S11) by conducting an experiment. The obtained optimal injection pattern may be stored in the data map for the injection control. The present injection pattern is defined by parameters, such as an injection stage, the injection timing of each injection, and the injection period, for example. The injection stage is a number of injections in one burning cycle. The injection period is equivalent to the injection quantity. In this way, the injection control map indicates the relationship between the parameters and the optimal injection pattern.

[0039] The injection pattern is obtained from the injection control map and is corrected using a correction coefficient. For example, the target value is calculated by diving the value on the injection control map by the correction coefficient. Thus, the injection pattern at the time and an instruction signal, which corresponds to the injection pattern and is to be outputted to the injector 20, is obtained. The correction coefficient is stored in, for example, the EEPROM of the ECU30 and separately updated. The correction coefficient (strictly, predetermined coefficient multiple coefficients) is successively updated by a separate processing in an operation of the engine.

[0040] In the setting of the injection pattern at step S12, data maps may be respectively created separately for the injection patterns, each including identical elements such as the injection stage. Alternatively, a data map may be created for the injection pattern, which includes some of or all the elements.

[0041] The injection pattern, which is set in this way, and the command value as the instruction signal, which corresponds to the injection pattern, are used at subsequent step S13. Specifically, at step S13, the injector 20 is controlled based on the command value as the instruction signal. In particular, the injector 20 is controlled according to the instruction signal outputted to the injector 20. The series of processings in FIG. 3 is terminated after performing the control of the present injector 20.

[0042] Next, a creation procedure of the injection control map, which is used at step S12, is described.

[0043] The present injection control map is created based on an examination result, which is conducted before shipment of the injector 20 from the factory. First, the examination as an injection characteristic examination is performed for each of the injectors 20(#1) to 20 (#4). Thereafter, individual difference information, which is obtained by the examination, is stored in the IC memory 26 as a storage unit (memory unit). The individual difference information indicates the injection characteristic of each injector 20. Then, the individual difference information is transmitted from each IC memory 26 to the ECU30 through a communication unit 31 (FIGS. 1, 4), which is provided to the ECU30. The transmission may be a non-contact wireless transmission or a wired transmission.

[0044] The injection characteristic examination is conducted in a mode shown in FIG. 4. First, the tip end of the injector 20 is put in a vessel 50. Then, high-pressure fuel is supplied to the fuel inlet hole 22 of the injector 20, whereby fuel is injected from the nozzle holes 20f into the vessel 50. At the present examination, the high-pressure fuel may be supplied using the fuel pump 11 shown in an FIG. 1. Alternatively, as shown in FIG. 4, the high-pressure fuel may be supplied using a fuel pump 52, which is exclusively provided for the examination. The high-pressure pipe 14 and the common rail 12, which are shown in FIG. 1, need not be connected to the pressure sensor 20a, which is mounted to the injector 20. The pressure sensor 20a may be directly supplied with high-pressure fuel from the fuel pump 11 or the fuel pump 52, which is provided for the examination.

[0045] The inner periphery of the vessel 50 is provided with a strain gauge 51. The strain gauge 51 detects pressure change, which is caused by a test injection, and outputs its detection result to a measuring instrument 53. The measuring instrument 53 includes a control unit, which is configured with a microcomputer, and the like. The control portion of the measuring instrument 53 calculates the injection rate of fuel injected from injector 20 based on the detection result of the strain gauge 51, the detection result indicating the injection pressure. As shown in FIG. 4, the measuring instrument 53 outputs the instruction signal, and the solenoid 20b of the injector 20 inputs the instruction signal. The measuring instrument 53 inputs the detection result of the pressure sensor 20a as the detected pressure.

[0046] Instead of calculating the change in injection rate based on the injection pressure, which is detected by using the strain gauge 51, the change in injection rate may be estimated from contents of the injection instruction. In this case, the strain gauge 51 can be omitted.

[0047] FIG. 5 shows a time chart showing changes in drive current, changes in injection rate, and changes in detected pressure through the examination. The top chart from the upper side in FIG. 5 shows the driving current as the instruction signal transmitted to the solenoid 20b. The second chart in FIG. 5 shows the injection rate. The bottom chart in FIG. 5 shows the detected pressure of the pressure sensor 20a. The present examination result is obtained by once opening and closing operation of the nozzle holes 20f.

[0048] In the present embodiment, such an examination is performed in each of multiple examination conditions where the pressure P0 of fuel supplied to the fuel inlet hole 22 at the time point in advance of the P1, is changed. The examinations are performed in the multiple examination conditions, because variation in injection characteristic is not determined uniquely in dependence upon the individual difference of injector 20. Specifically, the variation in injection characteristic also changes in dependence upon fueling pressure in the common rail 12. Therefore, in the present embodiment, by using the actual measurement result in the multiple examination conditions, in which the fueling pressure is variously modified, the variation in injection characteristic caused in dependence upon the individual difference is compensated, in addition to consideration of influence caused by the fueling pressure.

[0049] As follows, change in injection rate is described with reference to the second chart in FIG. 5B. First, energization of the solenoid 20b is started at the time point (energization start time point) Is, thereafter fuel injection from the nozzle holes 20f is started at the transition point R3. Thus, the injection rate starts increasing at the transition point R3. That is, actual injection is started. Then, the injection rate reaches at the maximum injection rate at the transition point R4, where the injection rate stops increasing. The needle valve 20c starts being lifted at the time of R3 and reaches the maximum lift at the transition point R4, and hence the injection rate stops increasing at the transition point R4.

[0050] In the present specification, the transition point is defined as follows. A second-order derivative of the injection rate or a second-order derivative of the detected result of the pressure sensor 20a is first calculated. The extremum at the point where the change is the maximum in a waveform, which indicates the second-order derivative, is the transition point of the waveform of the injection rate or the detected pressure. That is, the inflection point of the waveform of the second-order derivative is the transition point.

[0051] Subsequently, energization of the solenoid 20b is terminated at the time point Ie, thereafter the injection rate starts decreasing at the transition point R7. Then, the injection rate becomes zero at the transition point R8, where the actual fuel injection is terminated. The needle valve 20c starts being seated at the time of R7, and the needle valve 20c is completely seated at the transition point R8. Hence, the nozzle holes 20f are closed and the actual fuel injection is terminated at the transition point R8.

[0052] Next, change in detected pressure of the pressure sensor 20a is described with reference to the bottom chart in FIG. 5. The pressure P0, which is before the transition point P1, is the fueling pressure defined as an examination condition. The solenoid 20b is first supplied with the driving current. Thereafter, the detected pressure decrease at the transition point P1 before the injection rate starts increasing at the time point R3. It is caused because the control valve 23 opens the leak hole 24 at the time point P1, whereby the hydraulic pressure chamber Cd is decompressed. Then, when the hydraulic pressure chamber Cd is sufficiently decompressed, the detected pressure, which is decreasing from the P1, once stops decreasing at the transition point P2.

[0053] Subsequently, the detected pressure starts decreasing at the transition point P3, since the injection rate starts increasing at the time point R3. Subsequently, the decrease in the detected pressure stops at the transition point P4, since the injection rate reaches the maximum injection rate at the time point R4. Here, the decrease in detected pressure between the transition points P3 and P4 is larger than the decrease in detected pressure between the transition points P1 and P2.

[0054] Subsequently, the detected pressure increases at the transition point P5. It is caused because the control valve 23 closes the leak hole 24 at the time of P5, whereby the hydraulic pressure chamber Cd is pressurized. Then, when the hydraulic pressure chamber Cd is sufficiently pressurized, the detected pressure, which is increasing from the transition point P5, once stops increasing at the transition point P6.

[0055] Subsequently, the detected pressure starts increasing at the transition point P7, since the injection rate starts decreasing at the time point R7. Subsequently, the increase in detected pressure stops at the transition point P8, since the injection rate reaches zero at the time point R8, and actual fuel injection stops at the time point R8. Here, the increase in detected pressure between the transition points P7 and P8 is larger than the increase in detected pressure between the transition points P5 and P6. As shown in FIG. 8, the detected pressure subsequent to P8 decreases while repeating decreasing and increasing at a constant cycle T7 (FIG. 8).

[0056] In creating of the injection control map, individual difference information A1 to A7, B1, B2, and C1 to C3 (mentioned later) are first calculated based on the injection characteristic obtained from the examination result shown in FIG. 5. The obtained injection characteristic includes the change in detected pressure and the change in injection rate shown in FIG. 5. The calculated various individual difference information is stored in the IC memory 26. Then, the individual difference information stored in the IC memory 26 is transmitted to the ECU30. The ECU30 creates or modifies the injection control map based on the transmitted individual difference information.

<Individual Difference Information A1 to A7>

[0057] Next, the individual difference information A1 to A7 is described in detail. In addition, the procedure of the generation process of the individual difference information A1 to A7 and the writing process to the IC memory 26 are described with reference to FIGS. 6, 7. In the present embodiment, the calculation process and the writing process respectively shown in FIGS. 6, 7 are performed by a measurement operator using the measuring instrument 53. Alternatively, the measuring instrument 53 may automatically perform the series of processes, which are equivalent to those shown in FIGS. 6, 7.

[0058] The pressure sensor 20a is mounted to the injector 20. In the present structure, the pressure sensor 20a is located at the downstream of the common rail 12 with respect to the fuel flow in the fuel passage, which extends from the common rail 12 to the nozzle holes 20f. That is, the pressure sensor 20a is located on the side of the nozzle holes 20f in the fuel passage. Therefore, fluctuation, which is attributed to the change in injection rate, can be obtained as information from the waveform of the detected pressure of the pressure sensor 20a. Here, the fluctuation, which is attributed to the change in injection rate, may not be obtained in a structure where the pressure sensor 20a is located in the common rail 12. In addition, such a fluctuation in detected pressure has a high correlation with the change in injection rate, as indicated by the examination result in FIG. 5. Therefore, the change in actual injection rate can be estimated from the fluctuation in the waveform of the detected pressure, based on the present correlation.

[0059] The individual difference information A1 to A7 is defined by noting acquisition of the correlation between such a change in injection rate and fluctuation in detected pressure. Specifically, the individual difference information A1 to A7 represents a relationship between the change in injection rate (injection state) in the period between the transition points R3, R8 when the injector 20 injects fuel and the fluctuation in detected pressure of the pressure sensor 20a in the range between the transition points P1, P8, the fluctuation being attributed to the fuel injection.

[0060] In the process in FIG. 6, the detected pressure P0 at the energization start time point Is is first obtained at S10. At the energization start time point Is, energization of the solenoid 20b is started. Next, the detected pressure at the transition point P3, which is attributed to the actual injection start R3, is obtained at S20. In addition, the lapsed time T1 (first period) from the time point R3 (first reference point), in which the actual injection start is started, to the time point of the transition point P3 is measured at S20. Next, at S30, pressure difference P0-P3 is calculated as decrease in detected pressure caused by leakage in the time period from the energization start time point Is to the actual injection starts. Next, the relationship between the lapsed time T1 and the pressure difference P0-P3 is defined as individual difference information A1, and the individual difference information A1 is stored in the IC memory 26 at S40.

[0061] The individual difference information A2 to A4 is also stored in the IC memory 26 by a similar procedure at S21 to S41, S22 to S42, and S23 to S43. Specifically, pressure at the transition points P4, P7, P8, which are respectively attributed to the R4 (maximum injection rate reach), the R7 (injection rate decrease start), and the R8 (actual injection end), is obtained at S21 to S23. In addition, the lapsed time T2 (second period), T3 (third period), and T4 (fourth period) are measured at S21 to S23. The lapsed time T2, T3, T4 are respectively time periods from the actual injection start R3 (second, third, fourth reference point) to the transition points P4, P7, P8.

[0062] Next, at S31, pressure difference P3-P4 is calculated as decrease in detected pressure caused by leakage and fuel injection in the time period from the energization start time point Is to the transition point R4 where injection rate reaches the maximum injection rate. Next, at S32, pressure difference P3-P7 is calculated as decrease in detected pressure caused in the time period from the energization start time point Is to the transition point R7 where the injection rate starts decreasing. Next, at S33, pressure difference P3-P8 is calculated as change in detected pressure caused in the time period from the energization start time point Is to the transition point R8 where the actual injection ends. Each of the pressure difference P0-P3, P3-P4, and P3-P7 is represented by a positive value indicating pressure decrease (pressure drop). The pressure difference P3-P8 is represented by a negative value indicating pressure increase.

[0063] The relationship between the lapsed time T2 and the pressure difference P3-P4 is defined as the individual difference information A2 at S41. The relationship between the lapsed time T3 and the pressure difference P3-P7 is defined as the individual difference information A3 at S42. The relationship between the lapsed time T4 and the pressure difference P3-P8 is defined as the individual difference information A4 at S43. The individual difference information A2 to A4 is stored in the IC memory 26 at S41, S42, S43. Thus, the process before the factory shipment of the injector 20 in FIG. 6 ends.

[0064] In the process in FIG. 7, the detected pressure P0 at the time point Is is first obtained at S50. At the energization start time point Is, energization of the solenoid 20b is started. Next, the detected pressure at the transition point P3, which is attributed to the actual injection start R3, is obtained at S60. Next, the detected pressure at the transition point P4, which is attributed to the maximum injection rate reach R4, is obtained at S70. In addition, the lapsed time T5 (injection rate increase period) from the transition point P3, which is attributed to the actual injection start R3, to the transition point P4 is measured at S70. Next, pressure decrease rate $P\alpha$ ($P\alpha = (P3 - P4) / T5$) is calculated based on the detected pressure at the transition points P3, P4 and the period T5. Next, the relationship between the increase rate (injection-rate increase rate) $R\alpha$ of the injection rate and the pressure decrease rate $P\alpha$ is defined as the individual difference information A5, and the individual difference information A5 is stored in the IC memory 26 at S80.

[0065] The individual difference information A6 is also stored in the IC memory 26 by a similar procedure at S71, S81. Specifically, the detected pressure at the transition points P7, P8, which are attributed to the injection rate decrease start R7 and the actual injection end R8, is obtained at S71. In addition, the lapsed time T6 (injection rate decrease period) from the transition point P7 (sixth reference point), which is attributed to the injection rate decrease start R7, to the transition point P8 is measured at S71. Next, pressure increase rate $P\lambda$ ($P\lambda = (P7 - P8) / T6$) is calculated based on the detected pressure at the transition points P7, P8 and the period T6. Next, the relationship between the decrease rate (injection-rate decrease rate) $R\lambda$ in injection rate and the pressure increase rate PA is defined as the individual difference information A6, and the individual difference information A6 is stored in the IC memory 26 at S81.

[0066] Furthermore, detected pressure decrease $P\beta$ caused in the period time (fifth period) T5 is calculated. The time (fifth period) T5 is a time period from the time (fifth reference point) of the transition point P3, which is attributed to actual injection start R3, to the transition point P4, which is attributed to the maximum injection rate reach point R4. The detected pressure decrease $P\beta$ is the same as the pressure difference P3-P4. Therefore, the pressure difference P3-P4, which is calculated in the process at S41 in FIG. 6, may be used as the detected pressure decrease $P\beta$. The relationship between the calculated detected pressure decrease $P\beta$ and the calculated maximum injection rate $R\beta$ is defined as the individual difference information A7, and the individual difference information A7 is stored in the IC memory 26.

<Individual Difference Information B1, B2>

[0067] Next, the individual difference information B1, B2 is described in detail. The calculation process of the individual difference information B1, B2 and the writing process to the IC memory 26 are performed using the measuring instrument 53, similarly to the individual difference information A1 to A7.

[0068] The pressure sensor 20a is mounted to the injector 20. In the present structure, the pressure sensor 20a is located at the downstream of the common rail 12 with respect to the fuel flow in the fuel passage, which extends from the common rail 12 to the nozzle holes 20f. That is, the pressure sensor 20a is located close to the nozzle holes 20f in the fuel passage. Therefore, fluctuation, which is caused by the change in injection rate, can be obtained as information from the waveform of the detected pressure of the pressure sensor 20a. Here, the fluctuation, which is caused by the change in injection rate, may not be obtained in a structure where the pressure sensor 20a is located in the common rail 12.

[0069] As indicated by the examination result in FIG. 5, response delay (injection response time delay) T1 arises in the detection of the pressure fluctuation, which is caused in the nozzle holes 20f, using the pressure sensor 20a. The injection response time delay T1 is the time period from the pressure fluctuation arises in the nozzle holes 20f to the pressure fluctuation is transmitted to the pressure sensor 20a. Similarly, response delay (leak response time delay) Ta arises from the time point where fuel starts leaking from the leak hole 24 to the time point where fluctuation in detected pressure of the pressure sensor 20a is caused by the start of the fuel leakage.

[0070] Even in the same type of the injectors 20, individual difference is caused in the injection response time delay T1 and the leak response time delay Ta. The individual difference is attributed to the location of the pressure sensor 20a. Specifically, the individual difference is attributed to the fuel passage length La (FIG. 2) from the nozzle holes 20f to the pressure sensor 20a, the fuel passage length Lb (FIG. 2) from the leak hole 24 to the pressure sensor 20a, the passage crosssectional area thereof, and the like. Therefore, when the creating of the injection control map and the fuel injection control are performed based on at least one of the injection response time delay T1 and the leak response time delay Ta, the accuracy of the injection control can be enhanced.

[0071] The individual difference information B1, B2 is defined by noting acquisition of such an injection response time delay T1 and such a leak response time delay Ta. Specifically, the individual difference information B1 represents the injection response time delay T1 from the time point R3, in which the actual injection is started, to the transition point P3, which is attributed to the actual injection start R3. The injection response time delay T1 is the same as the lapsed time T1 (first period). Therefore, the lapsed time T1, which is calculated in the process at S20 in FIG. 6, may be used as the injection response time delay T1.

[0072] The individual difference information B2 represents the leak response time delay Ta from the energization start time point Is, in which energization to the solenoid 20b is started, to the transition point P1, which is attributed to the start of fuel leak from the leak hole 24. In the present embodiment, it is regarded that the energization start time point Is, in which energization of the solenoid 20b is started, is the same as the time point in which fuel leak actually starts. Thus, the injection response time delay T1 and the leak response time delay Ta, which are calculated in this way, are respectively defined as the individual difference information B1, B2, and the individual difference information B1, B2 are stored in the IC memory 26.

[0073] Instead of detecting the injection response time delay T1 in the process at S20 in this way, the injection response time delay T1 may be calculated in the following manner. Specifically, the bulk modulus of elasticity K, which will be describe below, and the fuel passage length La, Lb may be measured. Subsequently, the injection response time delay T1 may be calculated from the bulk modulus of elasticity K and the fuel passage length La. And subsequently, the leak response time delay Ta may be calculated from the bulk modulus of elasticity K and the fuel passage length Lb.

[0074] The bulk modulus of elasticity K is equivalent to the bulk modulus of elasticity of fuel in the entire of the fuel path, which extends from an outlet port 11e of the high-pressure pump 11a to the nozzle hole 20f of each of the injectors 20(#1) to 20(#4). The bulk modulus of elasticity K satisfies the formula $\Delta P = K \cdot \Delta V / V$, wherein ΔP: change in pressure accompanied with change in volume of fluid, V: volume, and ΔV: change in volume from the volume V, in pressure change caused in specific fluid. The inverse number of the coefficient K is equivalent to the compression ratio.

[0075] As follows, one example of calculation of the injection response time delay T1 based on the passage length La and the bulk modulus of elasticity K is described. The injection response time delay T1 can be defined by the formula of $T1 = La / v$, wherein the flow velocity of fuel is v. The flow velocity v can be calculated based on the bulk modulus of elasticity K. Similarly, the leak response time delay Ta can be defined by the formula of $Ta = Lb / v$. The flow velocity v can be calculated based on the bulk modulus of elasticity K.

[0076] Thus, the injection response time delay T1 and the leak response time delay Ta can be calculated by using the bulk modulus of elasticity K and the fuel passage length La, Lb as parameters in this way. Therefore, the parameters K, La, and Lb may be defined as the individual difference information B1, B2 instead of the injection response time delay T1 and the leak response time delay Ta, and the parameters K, La, and Lb may be stored in the IC memory 26.

<Individual Difference Information C1 to C3>

[0077] Next, the individual difference information C1 to C3 is described in detail with reference to FIGS. 8 to 12. The calculation process of the individual difference information C1 to C3 and the writing process to the IC memory 26 are performed using the measuring instrument 53, similarly to the individual difference information A1 to A7. FIG. 8 shows an examination result, which is obtained similarly to the examination result in FIG. 5. In each of FIGS. 9 to 12, the upper timing chart shows the instruction signal as the driving current with respect to the injector 20, and the lower timing chart shows a waveform indicating the fluctuation in detected pressure attributed to the instruction signal.

[0078] Here, to perform a multi-stage injection control so as to conduct multiple fuel injection within one burning cycle, it is necessary to care about the following subject.

As enclosed by the dashed dotted line Pe in FIG. 8, the fluctuation pattern of the former-stage injection and the fluctuation pattern of the latter-stage injection are partially overlapped one another to cause interference. Specifically, the fluctuation pattern of the fluctuation waveform, which corresponds to the n-th injection, is overlapped with the end portion of the fluctuation waveform, which is accompanied with the m-th injection after the end of the injection. The n-th injection is subsequent to the first injection. The m-th injection is in advance of the n-th injection. In the present embodiment, the m-th injection is the first injection. Hereafter, the fluctuation pattern is referred to a post-injection fluctuation pattern Pe.

[0079] In further detail, when injection is performed twice as shown in FIG. 9, the fluctuation waveform shown by the solid line L2b is generated with respect to the energization pulse shown by the solid line L2a in FIG. 9. As for the two injections indicated in FIG. 9, the fluctuation pattern, which is attributed only to the latter-stage injection at the latter-stage side and the fluctuation pattern of the former-stage injection at the former-stage side interfere with each other in the vicinity of the start timing of the latter-stage injection. Accordingly, it is difficult to recognize the fluctuation pattern, which is attributed only to the latter-stage injection.

[0080] As shown in FIG. 10, when only the former-stage injection is performed, the fluctuation waveform shown by the solid line L1 b is generated with respect to the energization pulse shown by the solid line L1 a in FIG. 10. FIG. 11 shows the solid lines L2a, L2b, which respectively depict the fluctuation waveforms in FIG. 9, and the dashed lines L1 a, L1b, which respectively depict the fluctuation waveforms in FIG. 10. As shown in FIG. 12, the fluctuation pattern shown by the solid line L2c, which is attributed only to the latter-stage injection, can be extracted by subtracting the fluctuation waveform L1b in FIG. 10 from the corresponding portion of the fluctuation waveform L2b in FIG. 9.

[0081] The individual difference information C1 to C3 is needed for extracting the fluctuation pattern L2c, which is attributed only to the latter-stage injection. That is, the individual difference information C1 to C3 is related to the post-injection fluctuation pattern Pe (FIG. 8), which is included in the fluctuation waveform of the detected pressure of the pressure sensor 20a, the fluctuation waveform being accompanied with one fuel injection. Referring to FIG. 8, the individual difference information C1 represents the amplitude S of the post-injection fluctuation pattern Pe, and the individual difference information C2 represents the cycle T7 of the post-injection fluctuation pattern Pe.

[0082] The individual difference information C3 represents a partial fluctuation pattern Py, which is shown by the solid line in FIG. 8. The partial fluctuation pattern Py appears at a cycle shorter than the cycle of a sine waveform Px shown by the dotted line in FIG. 8. The sine waveform Px is calculated from the amplitude S and the cycle T7 of the post-injection fluctuation pattern Pe. For example, the individual difference information C3 may be obtained by subtracting each portion of the fluctuation pattern Py from each corresponding portion of the sine waveform Px. Alternatively, information, which is related to attenuation such as an attenuation factor of the post-injection fluctuation pattern Pe, may be used as the individual difference information.

[0083] Preferably, in a case where a value included in each individual difference information A1 to A7, B1, B2, C1 to C3 exceed a predetermined upper limit, it is determined that a malfunction is caused. Specifically, for example, the measuring instrument 53 or the like may determine a malfunction to be caused in a case where the amplitude S and the cycle T7 of the post-injection fluctuation pattern Pe exceed the upper limit thereof.

[0084] As described above, this embodiment produces the following preferable effects.

(1) The individual difference information A1 to A7 is stored in the IC memory 26. The individual difference information A1 to A7 represents the relationship between the change in injection rate (injection state) in the period between the actual injection start R3 and the actual injection end R8 and the fluctuation in detected pressure of the pressure sensor 20a in the range between the transition points P1, P8, the fluctuation being attributed to the fuel injection. Therefore, the individual difference information A1 to A7 can be reflected on the injection control map, and the injection control can be performed in accordance with the present injection control map. Therefore, according to the present embodiment, the injection state of the injector 20 can be controlled with high accuracy, compared with a conventional device, which stores the Tq-Q characteristic as individual difference information and performs an injection control using the pre-stored Tq-Q characteristic.

(2) The injection response time delay T1 and the leak response time delay Ta as the individual difference information B1, B2 are stored in the IC memory 26. In the present structure, the individual difference information B1, B2 can be reflected on the injection control map, and the injection control can be performed in accordance with the present injection control map. Therefore, the injection state of the injector 20 can be controlled with high accuracy.

(3) The information related to the post-injection fluctuation pattern Pe as the individual difference information C1 to C3 is stored in the IC memory 26. In the present structure, the individual difference information C1 to C3 can be reflected on the injection control map, and the injection control can be performed in accordance with the present injection control map. Therefore, the injection state of the injector 20 can be controlled with high accuracy.

(4) In the examination for obtaining the individual difference information, the injector 20 is combined with the corresponding pressure sensor 20a in the state

where multiple injectors 20(#1) to 20(#4) are mounted to the engine. Specifically, for example, the injector of 20(#1) is combined with the pressure sensor 20a of the cylinder (#1) in the present examination. Therefore, the detection characteristic of the pressure sensor 20a, which is used in an actual engine operation, is reflected on the individual difference information A1 to A7. Thus, the injection state of the fuel injection valve can be controlled with high accuracy.

(5) The pressure sensor 20a is mounted to the injector 20. Therefore, the pressure sensor 20a, which is used in the injection characteristic examination before the factory shipment, can be restricted from being mounted to an injector 20, which is other than the corresponding injector 20. Specifically, for example, the pressure sensor 20a, which corresponds to the injector 20(#1) can be restricted from being mounted to one of the injector 20(#2) to 20(#4). Thus, an erroneous assembly can be restricted. In addition, in the present structure, the location of the pressure sensor 20a is closer to the nozzle holes 20f, compared with the structure in which the pressure sensor 20a is mounted to the high-pressure pipe 14, which connects the common rail 12 with the injector 20. Therefore, the pressure fluctuation at the nozzle holes 20f can be further accurately detected, compared with a structure in which the pressure fluctuation, which has been attenuated through the high-pressure pipe 14, is detected.

(Second Embodiment)

[0085] In the present embodiment, a master injector 20m and a master sensor 20am, which are different from the injector 20 and the pressure sensor 20a as examined objects, are prepared. The master injector 20m and the master sensor 20am are equivalent to a master device. The characteristic of the master device is beforehand measured through an examination to obtain a reference characteristic as a reference fluctuation mode. An error of each of the characteristics of the injector 20 and the pressure sensor 20a with respect to the reference characteristic is measured. The measured error as the individual difference information is stored in the IC memory 26 as a storage unit (memory unit). The injector 20 and the pressure sensor 20a are respectively equivalent to examined object devices.

[0086] The designed structure of the master injector 20m is the same as the designed structure of the injector 20 as the examined object. The designed location of the pressure sensor with respect to the master injector 20m is also the same as the designed location of the pressure sensor 20a with respect to the injector 20 as the examined object. However, the injection response time delay T1 and the like have a variation, which is caused by the individual difference in both the injectors, the individual difference in the pressure sensors 20a, variation in location of the pressure sensor 20a, and the like. In the present embodiment, such variation is defined as the characteristic.

[0087] Hereafter, the reference characteristic and the error are described with reference to FIG. 13.

[0088] The dashed dotted line in FIG. 13 indicates an examination result of the master device obtained by conducting the measurement process in FIG. 4. In the example shown in FIG. 13, as shown by the top and bottom charts, the phase is shifted so that the change in detected pressure of the master sensor 20am appears earlier than the change in detected pressure of the pressure sensor 20a as the examined object shown by the solid line. In the bottom chart in FIG. 13, the transition points of the change in detected pressure of the master sensor 20am are indicated by the reference numerals P1 m, P3m, P4m, P7m, P8m. The transition points P1 m, P3m, P4m, P7m, P8m respectively correspond to the transition points P1, P3, P4, P7, P8 of the change in detected pressure of the pressure sensor 20a as the examined object. The reference numerals $P\alpha m$, $P\beta m$, $P\lambda m$ respectively correspond to the pressure decrease rate $P\alpha$, the detected pressure decrease $P\beta$, and the pressure increase rate $P\lambda$ of the pressure sensor 20a as the examined object.

[0089] In the example in FIG. 13, an invalid injection period Tno is a time period from the energization start time point Is, at which the injection start instruction signal is outputted to the solenoid 20b, to the actual injection start point R3. In the invalid injection period Tno, an invalid injection period Tnom of the master injector 20m is the same as an invalid injection period Tno of the injector 20 as the examination object. The master device has an instruction-detection time delay T10m. The instruction-detection time delay T10m is a time period from the energization start time point Is, at which the injection start instruction signal is outputted to the solenoid 20b, to the time point P3m, at which the detected pressure of the pressure sensor 20a causes the fluctuation attributed to the fuel injection start. In the present embodiment, the instruction-detection time delay T10m is defined as a reference period as the reference fluctuation mode. Such a reference period T10m of the master device is beforehand measured. In addition, an instruction-detection time delay (instruction-response time delay) T10 of the examined object device, which includes the object injector 20 and the pressure sensor 20a as the examined objects, is also measured. An error $\Delta T10$ of the instruction-detection time delay T10 of the examined object device with respect to the reference period T10m of the master device is calculated as the instruction-detection error. The error $\Delta T10$ is stored in the IC memory 26.

[0090] First, the injection control map is created suitably to conformed values, which are obtained by conducting various examinations for the master device. Next, the injection control map, which is conformed to the master device, is corrected according to the instruction-detection error $\Delta T10$, which is stored in the IC memory 26. Specifically, the injection control map is corrected so that the injection pattern, which is stored in the injection control map, is advanced or retarded according to the instruction-detection error $\Delta T10$.

[0091] As described above, according to the present embodiment, the injection control map can be corrected in accordance with the conformed values by measuring the instruction-detection time delay T10 for the examined object device. Therefore, the injection rate shown by the middle chart in FIG. 13 need not be examined for the injector 20 as the examined object. Therefore, the preparing process of the injection control map can be enhanced in efficiency.

(Modification of Second Embodiment)

[0092] In the second embodiment, the instruction-detection time delay T10m from the injection instruction start time Is to the time point P3m, at which the detected pressure of the pressure sensor 20a causes the fluctuation attributed to the fuel injection start, is defined as the reference period as the reference fluctuation mode. The present definition may be modified.

[0093] · A time period from the injection instruction start time Is to the time point P4m, at which the detected pressure of the pressure sensor 20a causes the fluctuation attributed to the maximum injection rate reach, may be defined as the reference period as the reference fluctuation mode. In this case, an error of the time period Is to P4 of the examined object device with respect to the reference period is stored in the IC memory 26.

[0094] · A time period from the energization start time point Is to the time point P7m, at which the detected pressure of the pressure sensor 20a causes the fluctuation attributed to the injection rate decrease start, may be defined as the reference period as the reference fluctuation mode. In this case, an error of the time period Is to P7 of the examined object device with respect to the reference period is stored in the IC memory 26.

[0095] · A time period from the energization start time point Is to the time point P8m, at which the detected pressure of the pressure sensor 20a causes the fluctuation attributed to the actual injection end, may be defined as the reference period as the reference fluctuation mode. In this case, an error of the time period Is to P8 of the examined object device with respect to the reference period is stored in the IC memory 26.

[0096] · Instead of the definition of the time periods from the injection instruction start time Is respectively to the time points P3m, P4m, P7m, P8m as the reference periods as described above, a time point between any two of the time points P3m, P4m, P7m, P8m may be arbitrary defined as the reference period.

[0097] · The pressure decrease rate $P\alpha m$ of the detected pressure of the master sensor 20am attributed to the increase in injection rate may be defined as a reference pressure decrease rate $P\alpha m$ as the reference fluctuation mode. In this case, an error of the pressure decrease rate $P\alpha$ of the examined object device with respect to the reference pressure decrease rate $P\alpha m$ is stored in the IC memory 26.

[0098] · The pressure increase rate $P\lambda m$ of the detected pressure of the master sensor 20am attributed to the decrease in injection rate may be defined as a reference pressure increase rate $P\lambda m$ as the reference fluctuation mode. In this case, an error of the pressure increase rate $P\lambda$ of the examined object device with respect to the reference pressure increase rate $P\lambda m$ is stored in the IC memory 26.

[0099] · The decrease in detected pressure $P\beta m$ of the master sensor 20am, which is attributed to the period from the transition point P3 being attributed to the injection start to the transition point P4 being attributed to the maximum injection rate reach, may be defined as a reference pressure decrease $P\beta m$ as the reference fluctuation mode. In this case, an error of the pressure decrease $P\beta$ of the examined object device with respect to the reference pressure decrease $P\beta m$ is stored in the IC memory 26.

(Third Embodiment)

[0100] In the present embodiment, in addition to the creation of the injection control map described in the second embodiment, a malfunction of the examined object device is also detected.

[0101] The process related to the present malfunction detection is performed by a measurement operator using the measuring instrument 53 in FIG. 4. FIG. 14 shows the malfunction detection process. The present process may be performed at a manufacturing factory in the state where the injector 20 is mounted with the pressure sensor 20a and before the injector 20 is shipped from the factory. Alternatively, the present process may be performed at a service factory, in which various kinds of repair works and inspections are conducted, after the shipment of the injector 20 to a market, for example.

[0102] First, at M10 as a first measurement procedure, the instruction-injection time delay Tnom as a reference invalid period of the master injector 20m, which is mounted with the master sensor 20am as the master device, is measured. The instruction-injection time delay Tnom is the time period from the energization start time point Is to the fuel injection start time R3. At M10, the reference period T10m as the reference fluctuation mode is also measured.

[0103] Next, at M11 as a second measurement procedure, the instruction-injection time delay Tno as the invalid period and the instruction-detection time delay T10 of the injector 20 as the examined object device are measured. The present injector 20 is mounted with the pressure sensor 20a as the examined object.

[0104] Next, at M12, an error $\Delta T10$ of the instruction-detection time delay T10 of the examined object device with respect to the reference period T10m of the master device is calculated. At M12, an error ΔTno of the invalid period Tno of the examined object device with respect to the reference invalid period Tnom of the master device is also calculated.

[0105] Next, at M13 as a malfunction determination procedure, when the error ΔT10 of the instruction-detection time delay T10 is larger than a predetermined threshold thT10, the examined object device is determined to have caused a malfunction. In addition, it is further determined which one of the injector 20 and the pressure sensor 20a has caused the malfunction in such a manner described below.

[0106] The error ΔT10 of the instruction-detection time delay T10 includes an invalidity error and a sensor error. The invalidity error is attributed to the individual difference variation of the injector 20. The sensor error is attributed to variation in location of the pressure sensor 20a and variation in individual difference of the pressure sensor 20a. At M13, in consideration of the invalidity error and the sensor error, it is further determined which one of the injector 20 and the pressure sensor 20a has caused the malfunction based on the error ΔT10 of the instruction-detection time delay T10 and the error ΔTno of the invalid period Tno. For example, in the case where the examined object device is determined to have caused a malfunction, when the error ΔTno of the invalid period Tno is smaller than a predetermined threshold, the pressure sensor 20a is determined to have caused a malfunction.

[0107] As described above, according to present embodiment, the fuel injection device as the examined object can be easily determined to have caused a malfunction. In addition, it is easily determined whether the malfunction is caused in the pressure sensor 20a. In the present embodiment, in the case where it is not determined which device has caused a malfunction, measurement of the injection rate of the examined object device can be omitted.

(Modification of third Embodiment)

[0108] In the thirteenth embodiment, it is determined whether a malfunction is caused by defining the instruction-detection time delay T10m as the reference fluctuation mode and based on the error ΔT10 of the instruction-detection time delay of the examined object device with respect to the reference fluctuation mode. The present determination may be changed as follows similarly to the modification of a second embodiment.

[0109] · The time periods from the injection instruction start time Is respectively to the time points P3m, P4m, P7m, P8m may be defined as the reference fluctuation mode.

[0110] · Instead of the definition of the time periods from the injection instruction start time Is respectively to the time points P3m, P4m, P7m, P8m as the reference fluctuation mode as described above, a time point between any two of the time points P3m, P4m, P7m, P8m may be arbitrary defined as the reference period.

[0111] · The pressure decrease rate Pαm, the increase rate Pλm, and the pressure decrease Pβm may be defined as the reference fluctuation mode. In this case, it is determined whether a malfunction is caused based on an error of the pressure decrease rate Pα, the increase rate Pλ, and the pressure decrease Pβ of the examined object device with respect to the reference fluctuation mode.

(Fourth Embodiment)

[0112] FIG. 15 shows a procedure of a malfunction detection process according to the present embodiment. The present malfunction detection process is performed by a measurement operator using the measuring instrument 53 in FIG. 4. The present malfunction detection process may be performed at a manufacturing factory in the state where the injector 20 is mounted with the pressure sensor 20a and before the injector 20 is shipped from the factory. Alternatively, the present process may be performed at a service factory, in which various kinds of repair works and inspections are conducted, after the shipment of the injector 20 to a market, for example.

[0113] First, at M20 as a measurement procedure, the injection response time delay T1 (refer to FIG. 5) of the injector 20 as the examined object device is measured. The present injector 20 is mounted with the pressure sensor 20a as the examined object. Next, at M21 as a malfunction determination procedure, when the measured injection response time delay T1 is larger than a predetermined threshold thT1, the examined object device is determined to have caused a malfunction. Therefore, according to present embodiment, it is easily determined whether the pressure sensor 20a as the examined object have caused a malfunction.

(Other Embodiments)

[0114] The present invention is not limited to the above embodiments. The features of the embodiments may be arbitrarily combined.

[0115] · In addition to the decrease and increase in detected pressure, variations in decrease and increase in detected pressure may be stored in the IC memory 26 as individual difference information A8. Specifically, for example, when the examination in FIG. 5 is conducted for multiple times under the same condition, variation may be caused in the obtained result of the fluctuation waveform of the detected pressure. For example, such a variation may be combined with the individual difference information A1 to A7 and may be stored.

[0116] · The start point of the post-injection fluctuation pattern Pe may be stored in the IC memory 26 as the individual difference information C4, which is related to the post-injection fluctuation pattern Pe, together with the individual difference information C1 to C3. Preferably, the start point is the transition point P8, which is attributed to the actual injection end, in the fluctuation waveform of the detected pressure of the pressure sensor 20a, the fluctuation waveform being accompanied with one fuel injection.

[0117] · In the above embodiments, the first to fourth reference point is defined as the actual injection start point R3. Alternatively, the actual injection start point R3 may be defined as another time point. The fifth and sixth reference point may be also defined as another time point dissimilarly to the above embodiments. In the above embodiments, the period from the transition point P7 to the transition point P8 is defined as the injection rate decrease period T6, and the pressure increase rate PA is calculated based on the pressure increase in the injection rate decrease period T6. Alternatively, another period, which is included in the period between the transition points P7 to P8 may be defined as the injection rate decrease period, and the pressure increase rate Pλ may be calculated based on the pressure increase in the present injection rate decrease period. Similarly, another period, which is included between the transition points P3 to P4, may be defined as the injection rate increase period, and the pressure decrease rate Pα may be calculated based on the pressure decrease in the injection rate increase period.

[0118] · In the embodiment, the IC memory 26 is employed as the storage unit (memory unit) for storing the individual difference information. Alternatively, another memory storage such as a device using the QR code (registered trademark), may be employed as the storage unit.

[0119] · In the above embodiments, the IC memory 26 as the storage unit is mounted to the injector 20. Alternatively, the IC memory 26 may be mounted to a component other than the injector 20. Preferably, at the time of the factory shipment of the injector 20, the injector 20 is integrally mounted with the storage unit.

[0120] · The injector 20 may be provided with a piezo actuator, instead of the solenoid actuator shown in FIG. 2. A direct-acting injector may be also used. The direct-acting injector is operated without pressure leak from the leak hole 24 or the like, and a hydraulic pressure chamber Cd is not used to transmit driving power. The direct-acting injector may be a direct-acting piezo injector developed in recent years, for example. When the direct-acting injector is employed, the injection rate can be easily controlled.

[0121] · In the above embodiments, the pressure sensor 20a is mounted to the fuel inlet hole 22 of the injector 20. Alternatively, as shown by the dashed dotted line 200a in FIG. 2, a pressure sensor 200a may be mounted to the inside of the housing 20e, and fuel pressure in the fuel passage 25, which extends from the fuel inlet hole 22 to the nozzle holes 20f, may be detected.

[0122] Further in the case where the fuel inlet hole 22 is mounted with the pressure sensor as described above, the mounting structure of the pressure sensor 20a can be simplified, compared with the structure in which the inside of the housing 20e is mounted with the pressure sensor. On the other hand, in the structure in which the inside of the housing 20e is mounted with the pressure sensor, the location of the pressure sensor 20a is closer to the nozzle holes 20f, compared with the structure in which the fuel inlet hole 22 is mounted with the pressure sensor. Therefore, pressure fluctuation in the nozzle holes 20f can be further properly detected.

[0123] · The pressure sensor 20a may be mounted to the high-pressure pipe 14. In this case, the pressure sensor 20a is preferably mounted to the location at a predetermined distance from the common rail 12.

[0124] · A flow regulating unit may be provided to a connection between the common rail 12 and the high-pressure pipe 14 for regulating fuel flow from the common rail 12 to the high-pressure pipe 14. The present flow regulating unit is configured to blockade the passage when excessive fuel outflow is caused by, for example, fuel leak due to damage in the high-pressure pipe 14, the injector 20, or the like. For example, the flow regulating unit may be a valve element such as a ball element, which is configured to blockade the passage in the case of excessive flow. A flow damper, which is constructed by integrating the orifice 12a with the flow regulating unit, may be employed.

[0125] · The pressure sensor 20a may be located downstream of the orifice and the flow regulating unit with respect to the fuel flow. Alternatively, the pressure sensor 20a may be located downstream of at least one of the orifices and the flow regulating unit.

[0126] · According to the above embodiments, in the examination shown in FIG. 4, pressure being changed by test-injected fuel, is detected using the strain gauge 51. Alternatively, a pressure sensor, which is provided in the vessel 50, may be used for detecting the pressure, instead of the strain gauge 51.

[0127] · In the examination shown in FIG. 4, the change in injection rate of fuel may be estimated from the change in detection result (detected pressure) of the pressure sensor 20a. Further, the estimation result may be compared with the actual change in injection rate, which is obtained by using the strain gauge 51 or the pressure sensor for the examination. In this case, the deviation between the estimation result and the actual change may be reflected on the creation of the individual difference information A1 to A7, B1, B2, C1 to C3.

[0128] · The number of the fuel pressure sensor 20 may be arbitrary determined. For example, two or more sensors may be provided to a fuel passage for one cylinder.

[0129] · In the above embodiments, the pressure sensor 20a is provided to each cylinder. Alternatively, the pressure sensor 20a may be provided to only a part of the cylinders. For example, the pressure sensor 20a may be provided to only one cylinder. In this case, fuel pressure for other cylinders may be estimated based on the sensor output of the pressure sensor 20a.

[0130] · In the obtaining of the sensor output of the pressure sensor 20a by using the measuring instrument 53 in the examination or by using the ECU30 in an operation of the internal combustion engine at the time of injection control, the sensor output is preferably obtained at an interval such as 20 microseconds for recognizing the tendency of the pressure fluctuation. In this case, the interval is preferably shorter than 50 microseconds.

[0131] · It is also effective to additionally provide a rail pressure sensor for detecting pressure in the common rail 12, in addition to the pressure sensor 20a. In the present structure, the rail pressure in the common rail 12 can be further obtained, in addition to the pressure detected by the pressure sensor 20a. Thus, the fuel pressure can be detected at higher accuracy.

[0132] · The type of the engine and the system configuration as the controlled object may be also arbitrary changed according to the application or the like. According to the embodiments, the device and system are applied to the diesel engine as one example. Alternatively, the device and system are applicable to a spark ignition gasoline engine, in particular a direct-injection engine, for example. In a fuel injection system for a direct fuel-injection gasoline engine, a delivery pipe is provided for storing gasoline at high-pressure. In this case, high-pressure fuel is fed from the fuel pump to the delivery pipe, and the high-pressure fuel is distributed from the delivery pipe to the multiple injectors 20 and injected into the combustion chambers of the engine. In such a system, the delivery pipe is equivalent to the pressure-accumulation vessel. The device and system are not limited to be used for the control of a fuel injection valve, which injects fuel directly in a cylinder. The device and system may be used for a fuel injection valve, which injects fuel to an engine intake passage or an exhaust passage.

[0133] · In the third embodiment, it is determined to have caused a malfunction in the case where the error ΔT10 exceeds the threshold thT10. In the present determination of the third embodiment, the threshold thT10 may be set as a variable value. For example, the threshold thT10 may be set in a variable manner in accordance with pressure of fuel supplied to the injector when the reference period T10m and the instruction-detection time delay T10 are measured.

[0134] As described above, according to an aspect 1, a fuel injection device is configured to be supplied with fuel from a pressure-accumulation vessel (12). The fuel injection device includes a fuel injection valve (20) for injecting fuel, which is distributed from a pressure-accumulation vessel (12). The fuel injection device further includes a pressure sensor (20a) located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a nozzle hole (20f) of the fuel injection valve (20), the pressure sensor (20a) being located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12) and configured to detect pressure of fuel. The fuel injection device further includes a storage unit (26) for storing individual difference information, which indicates an injection characteristic of the fuel injection valve (20), the injection characteristic being obtained by an examination. The individual difference information indicates a relationship between an injection state when the fuel injection valve (20) performs fuel injection and a fluctuation in detected pressure of the pressure sensor (20a), the fluctuation being attributed to the fuel injection.

[0135] Pressure of fuel in the nozzle hole of the fuel injection valve is changed through the injection of fuel. In such a nozzle hole, pressure fluctuation has a high correlation with the injection state such as the actual injection start point, the maximum injection rate reach point, and the like. The inventor noted the present subject and conducted a study to specifically detect the injection state other than the injection quantity Q by detecting the pressure fluctuation. However, in the device according to JP-A-2006-200378, the pressure sensor as the rail pressure sensor is located at the pressure-accumulation vessel for detecting pressure of fuel in the pressure-accumulation vessel. Accordingly, the pressure fluctuation attributed to the injection may be attenuated within the pressure-accumulation vessel. Therefore, it is difficult to detect the pressure fluctuation with sufficient accuracy in such a conventional device.

[0136] According to the above embodiments, the pressure sensor is located in the fuel passage, which extends from the pressure-accumulation vessel to the nozzle hole of the fuel injection valve. The pressure sensor is located closer to the nozzle hole than the pressure-accumulation vessel. Therefore, the pressure sensor is capable of detecting pressure in the nozzle hole, before the pressure is attenuated in the pressure-accumulation vessel. Therefore, the pressure fluctuation attributed to the injection can be detected with sufficient accuracy. Thus, the injection state can be specifically detected based on the detection result. In the present structure, the injection state of the fuel injection valve can be specifically controlled with high accuracy.

[0137] Furthermore, according to the above embodiments, the individual difference information indicates a relationship between an injection state when the fuel injection valve injects fuel and a fluctuation in detected pressure of the pressure sensor, the fluctuation being attributed to the injection. The individual difference information is stored in the storage unit. For example, the relationship between the injection state and the pressure fluctuation may be examined as the injection characteristic before the factory shipment of the present fuel injection valve. The obtained injection characteristic in the examination may be stored as the individual difference information to the memory unit. Thus, the injection state can be controlled based on the relationship between the injection state and the pressure fluctuation, which are apt to cause an individual difference, as the individual difference information, which is obtained as a result of the beforehand examination. In the present structure, the injection state of the fuel injection valve can be specifically controlled with high accuracy.

[0138] Here, the detection characteristic of the pressure sensor also has an individual difference. Specifically, even in the same type of the pressure sensor, the output voltage with respect to the same pressure may differ. Therefore, in the examination before the factory shipment, when the examination is conducted using a different pressure sensor from the pressure sensor, which is actually mounted to the fuel injection device, the detection characteristic of the pressure sensor, which is used in the actual operation of the internal combustion engine, may not be reflected on the individual difference information. In view of the foregoing, according to the above embodiments, the individual difference information indicates the relationship between the injection state when the fuel injection valve performs fuel injection and a fluctuation in detected pressure of the pressure sensor, the fluctuation being attributed to the fuel injection. That is, the examination for a combination of the detected pressure of the pressure sensor and the fuel injection valve of the fuel injection device is conducted, and the individual difference information, which is obtained as a result of the examination, is used. Therefore, the detection characteristic of the pressure sensor, which is used in an actual engine operation, is reflected on the individual difference information. Thus, the injection state of the fuel injection valve can be controlled with high accuracy.

[0139] According to an aspect 2, the injection state includes at least one of an actual injection start point (R3), a maximum injection rate reach point (R4), an injection rate decrease start point (R7), an actual injection end point (R8), an increase rate (Rα) of increase in an injection rate, a decrease rate (RA) of the injection rate, and a maximum injection rate (Rβ). Fuel injection starts at the actual injection start point (R3). The injection rate reaches a maximum value at the maximum injection rate reach point (R4). The injection rate starts decreasing at the injection rate decrease start point (R7). Actual fuel injection ends at the actual injection end point (R8).

[0140] The time points, the injection rates, and the like are important parameters for specifically controlling the injection state, in addition to the injection quantity. That is, even when the injection quantity Q is the same, if the time points and the injection rates are changed, the combustion state of the engine is changed. As a result, output torque of the engine and the state of exhaust air are changed. In addition, the time points, injection rates, and the like have high correlation with the detected pressure fluctuation. Therefore, the relationship between the injection state such as the time points and the injection rates and the detected pressure fluctuation can be suitably used as the individual difference information.

[0141] According to an aspect 3, the individual difference information indicates a relationship between a first period (T1) and decrease in the detected pressure in the first period (T1). The first period (T1) is a time period from a first reference point (R3) to a point (P3) of transition. The first reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20). The point (P3) of transition appears in a waveform of the detected pressure. The transition is attributed to start of actual fuel injection. The present inventor found through an examination that the first period from the first reference time point to the transition point (P3) attributed to the actual injection start appears has a high correlation with the decrease in detected pressure in the first period. Therefore, according to the aspect 3, the injection state can be controlled at a target injection state with high accuracy in the control of the injection state based on the individual difference information.

[0142] According to an aspect 4, the first reference point (R3) is a time point at which fuel injection starts. In the present structure, the correlation between the decrease in detected pressure in the first period and the first period can be enhanced.

[0143] According to an aspect 5, the individual difference information indicates a relationship between a second period (T2) and decrease in the detected pressure in the second period (T2). The second period (T2) is a time period from a second reference point (R3) to a point (P4) of transition. The second reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20). The point (P4) of transition appears in a waveform of the detected pressure. The transition is attributed to a condition where injection rate reaches a maximum value. The present inventor found through an examination that the second period from the second reference time point to the transition point (P4) attributed to a condition where injection rate reaches a maximum value has a high correlation with the decrease in detected pressure in the second period.

[0144] Therefore, according to an aspect 5, the injection state can be controlled at a target injection state with high accuracy in the control of the injection state based on the individual difference information.

[0145] According to an aspect 6, the second reference point (R3) is a time point at which fuel injection starts. In the present structure, the correlation between the decrease in detected pressure in the second period and the second period can be enhanced.

[0146] According to an aspect 7, the individual difference information indicates a relationship between a third period (T3) and change in the detected pressure in the third period (T3). The third period (T3) is a time period from a third reference point (R3) to a point (P7) of transition. The third reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20). The point (P7) of transition appears in a waveform of the detected pressure. The transition is attributed to a condition where an injection rate starts decreasing. The present inventor found through an examination that the third period from the third reference time point to the transition point (P7) attributed to a condition where an injection rate starts decreasing has a high correlation with the change in detected pressure in the third period. Therefore, according to an aspect 7, the injection state can be controlled at a target injection state with high accuracy in the control of the injection state based on the individual difference information.

[0147] According to an aspect 8, the third reference point (R3) is a time point at which fuel injection starts. In the present structure, the correlation between the change in detected pressure in the third period and the third period can be enhanced.

[0148] According to an aspect 9, the individual difference information indicates a relationship between a fourth period (T4) and change in the detected pressure in the fourth period (T4). The fourth period (T4) is a time period from a fourth reference point (R3) to a point (P8) of transition. The fourth reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20). The point (P8) of transition appears in a waveform of the detected pressure. The transition is attributed to end of actual fuel injection. The present inventor found through an examination that the fourth period from the fourth reference time point to the transition point (P8) attributed to end of actual fuel injection has a high correlation with the change in detected pressure in the fourth period. Therefore, according to an aspect 9, the injection state can be controlled at a target injection state with high accuracy in the control of the injection state based on the individual difference information.

[0149] According to an aspect 10, the fourth reference point (R3) is a time point at which fuel injection starts. In the present structure, the correlation between the change in detected pressure in the fourth period and the fourth period can be enhanced.

[0150] According to an aspect 11, the individual difference information indicates a relationship between decrease ($P\beta$) in detected pressure in a fifth period (T5) and a maximum injection rate ($R\beta$). The fifth period (T5) is a time period from a fifth reference point (P3) to a point (P4) of transition. The fifth reference point (P3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20). The point (P4) of transition appears in a waveform of the detected pressure. The transition is attributed to a condition where an injection rate reaches a maximum value. The present inventor found through an examination that the decrease ($P\beta$) in detected pressure in the fifth period from the fifth reference time point to the transition point (P4) attributed to a condition where injection rate reaches a maximum value has a high correlation with the maximum injection rate ($R\beta$).

[0151] Therefore, according to the aspect 11, the injection state can be controlled at a target injection state with high accuracy in the control of the injection state based on the individual difference information.

[0152] According to an aspect 12, the individual difference information indicates a relationship between an increase rate ($R\alpha$) of increase in an injection rate in an injection rate increase period and a decrease rate ($P\alpha$) of decrease in the detected pressure. The injection rate increase period is in a time period from an actual injection start point (R3) to a maximum injection rate reach point (R4). The decrease in detected pressure is attributed to the increase in injection rate. The present inventor found through an examination that the increase rate ($R\alpha$) of increase in the injection rate in the injection rate increase period from the actual injection start point (R3) to the maximum injection rate reach point (R4) has a high correlation with the decrease rate ($P\alpha$) of decrease in the detected pressure, the decrease in detected pressure being attributed to the increase in injection rate. Therefore, according to an aspect 12, the injection state can be controlled at a target injection state with high accuracy in the control of the injection state based on the individual difference information.

[0153] According to an aspect 13, the injection rate increase period is the time period from the actual injection start point (R3) to the maximum injection rate reach point (R4). In the present structure, the correlation between the increase rate ($R\alpha$) of increase in the injection rate in the injection rate increase period and decrease in the detected pressure in the injection rate increase period can be enhanced.

[0154] According to an aspect 14, the individual difference information indicates a relationship between a decrease rate ($R\lambda$) of decrease in an injection rate in an injection rate decrease period and an increase rate ($P\lambda$) of increase in the detected pressure. The injection rate decrease period is in a time period from an injection rate decrease start point (R7) to an actual injection end point (R8). The increase in detected pressure is attributed to the decrease in injection rate. The present inventor found through an examination that the decrease rate ($R\lambda$) of decrease in the injection rate in the injection rate decrease period, which is in a time period from the actual injection start point (R3) to the actual injection end point (R8) has a high correlation with the increase rate ($P\lambda$) of increase in the detected pressure, the increase in detected pressure being attributed to the decrease in injection rate.

[0155] Therefore, according to an aspect 14, the injection state can be controlled at a target injection state with high accuracy in the control of the injection state based on the individual difference information.

[0156] According to an aspect 15, the injection rate decrease period is the time period from the injection rate decrease start point (R7) to the actual injection end point (R8). In the present structure, the correlation between the decrease rate ($R\lambda$) of decrease in the injection rate in the injection rate decrease period and increase in the detected pressure in the injection rate decrease period can be enhanced.

[0157] According to an aspect 16, the individual difference information indicates change in the detected pressure and a variation in the change in the detected pressure. Therefore, the variation in the change in the detected pressure can be considered in the control of the injection state based on the individual difference information. For example, the injection state can be controlled at the target injection state with high accuracy by reducing reflection of the variation on the injection control in the state where change in the detected pressure, which is stored as the individual difference information, has a large variation.

[0158] According to an aspect 17, a fuel injection device is configured to be supplied with fuel from a pressure-accumulation vessel (12). The fuel injection device includes a fuel injection valve (20) for injecting fuel, which is distributed from a pressure-accumulation vessel (12). A fuel injection device further includes a pressure sensor (20a) located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a nozzle hole (20f) of the fuel injection valve (20), the pressure sensor (20a) being located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12) and configured to detect pressure of fuel. A fuel injection device further includes a storage unit (26) for storing individual difference information, which indicates an injection characteristic of the fuel injection valve (20), the injection characteristic being obtained by an examination. The individual difference information indicates an error of an object fluctuation mode of the fuel injection valve (20) and pressure sensor (20a) as examined objects with respect to a reference fluctuation mode of a master sensor (20am) and a master fuel injection valve (20m). Each of the object fluctuation mode and the reference fluctuation mode represents a fluctuation in detected pressure subsequent to an output of an injection instruction signal. The object fluctuation mode is obtained by an examination of the fuel injection valve (20) and pressure sensor (20a) as the examined objects, which are respectively different from the master fuel injection valve (20m) and the master sensor (20am).

[0159] According to the aspect 17, the pressure sensor is also located closer to the injection hole than the pressure-accumulation vessel. Therefore, fluctuation in pressure accompanied with the fuel injection can be detected with high accuracy, similarly to the aspect 1. Therefore, the injection state can be specifically detected based on the detection result. Thus, the injection state of the fuel injection valve can be specifically detected with high accuracy.

[0160] According to the aspect 17, by beforehand detecting the injection state of both the master injection valve and the master sensor as master devices as a known value, the injection characteristic of the fuel injection valve as the examined object can be calculated based on the known value and the error.

[0161] Therefore, according to the aspect 17, by measuring a conformed value, which includes various parameters for various control of the engine and conformed to the master devices and by correcting the conformed value based on the error stored in the storage unit, the conformed value for the fuel injection valve as the examined object can be easily obtained. The various parameters include, for example, the engine rotation speed NE, an optimal injection patterns with respect to the engine load, and the like. The optimal injection patterns may include the injection quantity, the injection timing and the like in a single injection. The optimal injection patterns may include the injection quantity, the injection timing, and the like in each stage in a multi-stage injection.

[0162] According to an aspect 18, the reference fluctuation mode is an instruction-detection time delay (T10m) from a time point, at which an injection instruction signal is outputted, to a fluctuation appearing point (P3, P3m, P4, P4m, P7, P7m, P8, P8m), at which fluctuation occurs in the detected pressure of the master sensor (20am). The error is an instruction-detection error (ΔT10) of the instruction-detection time delay (T10), which is obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode (T10m).

[0163] In the present structure, the response time delay T1 or the like of the fuel injection valve as the examined object can be calculated based on the instruction-detection error (ΔT10) by beforehand measuring the injection characteristic of the master device as the known value. The known value may be the injection-detection time delay T1 m in FIG. 13 from the fuel injection start though the nozzle hole to the time point at which fluctuation occurs in the detected pressure of the pressure sensor, the fluctuation being attributed to the fuel injection start. In this case, the response time delay T1 can be calculated by adding the injection-detection time delay T1 m to the injection-detection error ΔT10, which is stored in the storage unit.

[0164] Therefore, according to the aspect 18, by measuring a conformed value, which includes various parameters for various control of the engine and conformed to the master devices and by correcting the conformed value based on the instruction-detection error ΔT10 stored in the storage unit, the conformed value for the fuel injection valve as the examined object can be easily obtained. The various parameters include, for example, the engine rotation speed NE, an optimal injection patterns with respect to the engine load, and the like. The optimal injection patterns may include the injection quantity, the injection timing and the like in a single injection. The optimal injection patterns may include the injection quantity, the injection timing, and the like in each stage in a multi-stage injection.

[0165] According to an aspect 19, the individual difference information includes at least one of an invalidity error and a sensor error, which are obtained by an examination of the fuel injection valve (20) and the pressure sensor (20a) as the examined objects. The invalidity error is an error of an instruction-injection time delay (Tno) with respect to a reference invalid period (Tnom). The instruction-injection time delay (Tno) is a time period from a time point, at which an injection instruction signal is outputted, to a time point at which fuel injection starts. The reference invalid period (Tnom) is the instruction-injection time delay (Tnom) of the master fuel injection valve (20m) and the master pressure sensor (20ma). The sensor error is obtained by subtracting the invalidity error from an instruction-detection error (ΔT10).

[0166] The instruction-detection error includes an invalid error and a sensor error. The invalid error is attributed to the individual difference variation of the injector. The sensor error is attributed to variation in location of the pressure sensor and variation in individual difference of the pressure sensor. In the example of FIG. 13, since the invalidity error is zero, the instruction-detection error $\Delta T10$ is equal to the sensor error $\Delta T10$. Therefore, according to the aspect 19, in which the invalidity error or the sensor error are stored in the storage unit in addition to the instruction-detection error deltaT10, the items of the invalidity error contained in the instruction-detection error and the sensor error can be also obtained as information. Thus, the injection state of the fuel injection valve can be further specifically controlled with high accuracy.

[0167] An aspect 20 is as an example of the fluctuation appearing point. According to the aspect 20, the fluctuation appearing point is one of: a time point (P3, P3m) at which fluctuation, which is attributed to start of fuel injection, occurs; a time point (P4, P4m) at which fluctuation, which is attributed to a condition where an injection rate reaches a maximum value, occurs; a time point (P7, P7m) at which fluctuation, which is attributed to a condition where an injection rate starts decreasing, occurs; and a time point (P8, P8m) at which fluctuation, which is attributed to end of fuel injection, occurs. In the present structure, the injection state of the fuel injection valve as the examined object can be suitably calculated.

[0168] According to an aspect 21, the reference fluctuation mode is a reference pressure decrease rate ($P\alpha m$) of the detected pressure of the master sensor (20am), the reference pressure decrease rate ($P\alpha m$) being attributed to increase in injection rate. The error is a decrease rate error of a pressure decrease rate ($P\alpha$), which is obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode ($P\alpha m$). In the present structure, the injection state of the fuel injection valve as the examined object can be suitably calculated.

[0169] According to an aspect 22, the reference fluctuation mode is a reference pressure increase rate ($P\lambda m$) of the detected pressure of the master sensor (20am), the reference pressure increase rate ($P\lambda m$) being attributed to decrease in injection rate. The error is an increase rate error of a pressure increase rate (PA), which is obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode (PAm). In the present structure, the injection state of the fuel injection valve as the examined object can be suitably calculated.

[0170] According to an aspect 23, the reference fluctuation mode is a reference pressure decrease ($P\beta m$) of detected pressure of the master sensor (20am), the reference pressure decrease ($P\beta m$) being attributed to a period from an injection start to that injection rate reaches a maximum value. The error is a decrease error of the pressure decrease ($P\beta$), which is obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode ($P\beta m$). In the present structure, the injection state of the fuel injection valve as the examined object can be suitably calculated.

[0171] According to an aspect 24, the individual difference information includes a plurality of information items, which is respectively obtained by conducting a plurality of examinations. The plurality of examinations respectively includes a plurality patterns of examination conditions, which are different from each other in pressure of fuel supplied to the fuel injection valve (20). Each of the information items is correlated to each of the plurality of patterns and stored. In the present structure, even in the case where the relationship between the injection state and the fluctuation in detected pressure is changed in dependence upon the supply pressure of fuel to the fuel injection valve, the injection state can be controlled based on the individual difference information according to the supply pressure. Therefore, the injection state can be controlled with high precision.

[0172] Here, according to the aspect 1, the individual difference information obtained as a result of the examination in which the detected pressure and the fuel injection valve of the pressure sensor, which is mounted to the corresponding fuel injection device, are combined. Therefore, the detection characteristic of the pressure sensor actually used in an actual operation of the internal combustion engine can be reflected on the individual difference information. Therefore, according to an aspect 25, the pressure sensor is mounted to the fuel injection valve. In the present structure, the pressure sensor, which is used in the injection characteristic examination before the factory shipment, can be restricted from being mounted to an injector, which is other than the corresponding injector. Thus, an erroneous assembly can be restricted.

[0173] Further, according to an aspect 25, the location of the pressure sensor is closer to the injection hole, compared with the structure in which the pressure sensor is mounted to the high-pressure pipe, which connects the pressure-accumulating vessel with the injector. Therefore, pressure fluctuation at the injection holes can be further accurately detected, compared with a structure in which the pressure fluctuation, which has been attenuated through the high-pressure pipe, is detected.

[0174] The pressure sensor is mounted to the fuel injection valve. According to an aspect 26, the pressure sensor (20a) is located at a fuel inlet hole (22) of the fuel injection valve (20). According to an aspect 27, the pressure sensor (20a) is located in the fuel injection valve (20) for detecting pressure of fuel in an inner fuel passage (25), which extends from the fuel inlet hole (22) to the nozzle hole (20f).

[0175] Further in the case where the fuel inlet hole is mounted with the pressure sensor as described above, the mounting structure of the pressure sensor can be simplified, compared with the structure in which the inside of the fuel injection valve is mounted with the pressure sensor. On the other hand, in the structure in which the inside of the fuel injection valve is mounted with the pressure sensor, the location of the pressure sensor is closer to the injection holes, compared with the structure in which the fuel inlet hole is mounted with the pressure sensor. Therefore, pressure fluctuation in the injection holes can be further properly detected.

[0176] According to an aspect 28, an orifice (12a) is located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a fuel inlet hole (22) for attenuating pulsation in pressure of fuel flowing from the pressure-accumulation vessel (12). The pressure sensor (20a) is located downstream of the orifice (12a) with respect to fuel flow. In the case where the pressure sensor is located upstream of the orifice, fluctuation in pressure, which has been attenuated through the orifice, is detected. By contrast, according to the aspect 28, the pressure sensor is located downstream of the orifice. Therefore, pressure fluctuation can be detected before being attenuated through the orifice. Therefore, pressure fluctuation in the nozzle hole can be further properly detected.

[0177] Therefore, according to the aspect 1, when the individual difference information includes the relationship between the injection state and the fluctuation in the detected pressure, the individual difference information may include more information items compared with the structure of JP-A-2006-200378 in which the Tq-Q characteristic is stored as the individual difference information.

[0178] Therefore, according to an aspect 29, the storage unit is an integrated circuit memory (IC memory). Therefore, the storage unit can be increased in storage capacity, compared with the QR code (registered trademark). Therefore, the storage unit is capable of storing a large amount of information and suitable for increased information.

[0179] According to an aspect 30, a fuel injection system includes the above fuel injection device. The fuel injection system further includes the pressure-accumulation vessel (12) configured to accumulate fuel at predetermined pressure and distribute the accumulated fuel to a plurality of fuel injection valves. The fuel injection system is capable of producing the above various effects.

[0180] The inventors conceived that a malfunction caused in the fuel injection device, in which the pressure sensor is located closer to the nozzle hole than the pressure-accumulating vessel, can be easily determined by the methods according the aspects 31, 32.

[0181] Specifically, according to an aspect 31, the method includes first-measuring a fluctuation in detected pressure mode of the pressure sensor (20a), the fluctuation appearing after an output of an injection instruction signal. The method further includes second-measuring an object fluctuation mode by conducting an examination for the fuel injection valve (20) and pressure sensor (20a) as examined objects of the malfunction. The method further includes determining that the examined objects malfunction when an error of the object fluctuation mode with respect to a reference fluctuation mode as a reference is larger than a threshold.

[0182] When variation in location of the pressure sensor and the individual difference of the pressure sensor is out of an allowable range, the deviation of the detected fluctuation mode with respect to the standard fluctuation mode is larger than the threshold. Therefore, according to claim 31, which includes the measuring and determining, a malfunction caused in the pressure sensor can be easily determined. The measuring and the determining may be conducted in a manufacturing factory before the shipment and a service factory for performing repair work and examination after the shipment.

[0183] Therefore, according to an aspect 32, the method includes first-measuring a reference fluctuation mode by conducting an examination for a master fuel injection valve (20m) and a master sensor (20am). The method further includes second-measuring an object fluctuation mode by conducting an examination for the fuel injection valve (20) and pressure sensor (20a) as examined objects of the malfunction. Each of the reference fluctuation mode and the object fluctuation mode represents a fluctuation in detected pressure subsequent to an output of an injection instruction signal. The master fuel injection valve (20m) and the master sensor (20am) being respectively different from the fuel injection valve (20) and pressure sensor (20a). The method further includes determining that at least one of the examined objects malfunctions when a deviation between the object fluctuation mode and the reference fluctuation mode is larger than a threshold.

[0184] When variation in location of the pressure sensor and the individual difference of the pressure sensor is out of an allowable range, or when variation in the instruction-injection delay time (invalid period), which is attributed to the variation in individual difference of the fuel injection valve, is out of an allowable range, the deviation of the detected fluctuation mode with respect to the standard fluctuation mode is larger than the threshold. Therefore, according to claim 32, which includes the measuring and determining, a malfunction caused in the pressure sensor or the fuel injection valve can be easily determined. The measuring and the determining may be conducted in a manufacturing factory before the shipment and a service factory for performing repair work and examination after the shipment.

[0185] The above structures of the embodiments can be combined as appropriate. The above processings such as calculations and determinations are not limited being executed by the ECU 30. The control unit may have various structures including the ECU 30 shown as an example.

[0186] The above processings such as calculations and determinations may be performed by any one or any combinations of software, an electric circuit, and the like. The software may be stored in a storage medium, and may be transmitted via a transmission device such as a network device. The electric circuit may be an integrated circuit, and may be a discrete circuit such as a hardware logic configured with electric or electronic elements or the like. The elements producing the above processings may be discrete elements and may be partially or entirely integrated.

[0187] It should be appreciated that while the processes of the embodiments of the present invention have been described herein as including a specific sequence of steps, further alternative embodiments including various other sequences of these steps and/or additional steps not disclosed herein are intended to be within the steps of the present invention.

[0188] Various modifications and alternations may be diversely made to the above embodiments without departing from the spirit of the present invention.

[0189] A fuel injection device includes a fuel injection valve (20) for injecting fuel, which is distributed from a pressure-accumulation vessel (12). A pressure sensor (20a) is located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a nozzle hole (20f) of the fuel injection valve (20). The pressure sensor (20a) is located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12) and configured to detect pressure of fuel. The fuel injection device further includes a storage unit (26) for storing individual difference information, which indicates an injection characteristic of the fuel injection valve (20). The injection characteristic is obtained by an examination. The individual difference information indicates a relationship between an injection state when the fuel injection valve (20) performs fuel injection and a fluctuation in detected pressure of the pressure sensor (20a). The fluctuation is attributed to the fuel injection.

Claims

1. A fuel injection device configured to be supplied with fuel from a pressure-accumulation vessel (12), the fuel injection device comprising:

   a fuel injection valve (20) for injecting fuel, which is distributed from the pressure-accumulation vessel (12);
   a pressure sensor (20a) located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a nozzle hole (20f) of the fuel injection valve (20), the pressure sensor (20a) being located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12) and configured to detect pressure of fuel; and
   a storage unit (26) for storing individual difference information, which indicates an injection characteristic of the fuel injection valve (20), the injection characteristic being obtained by an examination,

   wherein the individual difference information indicates a relationship between an injection state when the fuel injection valve (20) performs fuel injection and a fluctuation in detected pressure of the pressure sensor (20a), the fluctuation being attributed to the fuel injection.

2. The fuel injection device according to claim 1,
   wherein the individual difference information indicates a relationship between a first period (T1) and decrease in the detected pressure in the first period (T1),
   the first period (T1) is a time period from a first reference point (R3) to a point (P3) of transition,
   the first reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20),
   the point (P3) of transition appears in a waveform of the detected pressure, and
   the transition is attributed to start of actual fuel injection.

3. The fuel injection device according to any one of claims 1 or 2,
   wherein the individual difference information indicates a relationship between a second period (T2) and decrease in the detected pressure in the second period (T2),
   the second period (T2) is a time period from a second reference point (R3) to a point (P4) of transition,
   the second reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20),
   the point (P4) of transition appears in a waveform of the detected pressure, and
   the transition is attributed to a condition where an injection rate reaches a maximum value.

4. The fuel injection device according to any one of claims 1 to 3,
   wherein the individual difference information indicates a relationship between a third period (T3) and change in the detected pressure in the third period (T3),
   the third period (T3) is a time period from a third reference point (R3) to a point (P7) of transition,
   the third reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20),
   the point (P7) of transition appears in a waveform of the detected pressure, and
   the transition is attributed to a condition where an injection rate starts decreasing.

5. The fuel injection device according to any one of claims 1 to 4,
   wherein the individual difference information indicates a relationship between a fourth period (T4) and

change in the detected pressure in the fourth period (T4), the fourth period (T4) is a time period from a fourth reference point (R3) to a point (P8) of transition, the fourth reference point (R3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20), the point (P8) of transition appears in a waveform of the detected pressure, and the transition is attributed to end of actual fuel injection.

6. The fuel injection device according to any one of claims 1 to 5, wherein the individual difference information indicates a relationship between decrease (Pβ) in detected pressure in a fifth period (T5) and a maximum injection rate (Rβ), the fifth period (T5) is a time period from a fifth reference point (P3) to a point (P4) of transition, the fifth reference point (P3) is subsequent to an output of an injection instruction (Is) to the fuel injection valve (20), the point (P4) of transition appears in a waveform of the detected pressure, and the transition is attributed to a condition where an injection rate reaches a maximum value.

7. The fuel injection device according to any one of claims 1 to 6, wherein the individual difference information indicates a relationship between an increase rate (Rα) of increase in an injection rate in an injection rate increase period and a decrease rate (Pα) of decrease in the detected pressure, or the individual difference information indicates a relationship between a decrease rate (Rλ) of decrease in an injection rate in an injection rate decrease period and an increase rate (Pλ) of increase in the detected pressure, wherein the injection rate increase period is in a time period from an actual injection start point (R3) to a maximum injection rate reach point (R4), the decrease in detected pressure is attributed to the increase in injection rate, the injection rate decrease period is in a time period from an injection rate decrease start point (R7) to an actual injection end point (R8), and the increase in detected pressure is attributed to the decrease in injection rate.

8. The fuel injection device according to any one of claims 1 to 7, wherein the individual difference information indicates change in the detected pressure and a variation in the change in the detected pressure.

9. A fuel injection device configured to be supplied with fuel from a pressure-accumulation vessel (12), the fuel injection device comprising:

a fuel injection valve (20) for injecting fuel, which is distributed from the pressure-accumulation vessel (12);
a pressure sensor (20a) located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a nozzle hole (20f) of the fuel injection valve (20), the pressure sensor (20a) being located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12) and configured to detect pressure of fuel; and
a storage unit (26) for storing individual difference information, which indicates an injection characteristic of the fuel injection valve (20), the injection characteristic being obtained by an examination,

wherein the individual difference information indicates an error of an object fluctuation mode of the fuel injection valve (20) and pressure sensor (20a) as examined objects with respect to a reference fluctuation mode of a master sensor (20am) and a master fuel injection valve (20m), each of the object fluctuation mode and the reference fluctuation mode represents a fluctuation in detected pressure subsequent to an output of an injection instruction signal, and the object fluctuation mode is obtained by an examination of the fuel injection valve (20) and pressure sensor (20a) as the examined objects, which are respectively different from the master fuel injection valve (20m) and the master sensor (20am).

10. The fuel injection device according to claim 9, wherein the reference fluctuation mode is an instruction-detection time delay (T10m) from a time point, at which an injection instruction signal is outputted, to a fluctuation appearing point (P3, P3m, P4, P4m, P7, P7m, P8, P8m), at which fluctuation occurs in the detected pressure of the master sensor (20am), and the error is an instruction-detection error (ΔT10) of the instruction-detection time delay (T10), which is obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode (T10m).

11. The fuel injection device according to claim 9, wherein the reference fluctuation mode is a reference pressure decrease rate (Pαm) of the detected pressure of the master sensor (20am), the reference pressure decrease rate (Pαm) being attributed to increase in injection rate, the error being a decrease rate error of a pressure decrease rate (Pα), which is

obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode (Pαm), or
the reference fluctuation mode is a reference pressure increase rate (PAm) of the detected pressure of the master sensor (20am), the reference pressure increase rate (PAm) being attributed to decrease in injection rate, the error being an increase rate error of a pressure increase rate (PA), which is obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode (PAm).

12. The fuel injection device according to claim 9, wherein the reference fluctuation mode is a reference pressure decrease (Pβm) of detected pressure of the master sensor (20am), the reference pressure decrease (Pβm) being attributed to a period from an injection start to that injection rate reaches a maximum value, and
the error is a decrease error of the pressure decrease (Pβ), which is obtained by the examination of the fuel injection valve (20) and pressure sensor (20a) as the examined object, with respect to the reference fluctuation mode (Pβm).

13. The fuel injection device according to any one of claims 1 to 12,
wherein the pressure sensor (20a) is provided to the fuel injection valve (20), or the fuel injection device further comprising:

an orifice (12a) located in a fuel passage (25), which extends from the pressure-accumulation vessel (12) to a fuel inlet hole (22) for attenuating pulsation in pressure of fuel flowing from the pressure-accumulation vessel (12),

wherein the pressure sensor (20a) is located downstream of the orifice (12a) with respect to fuel flow.

14. A method for determining a malfunction caused in a fuel injection device, the fuel injection device including a fuel injection valve (20), which is configured to inject fuel distributed from a pressure-accumulation vessel (12), and a pressure sensor (20a), which is located in a fuel passage (25) extending from the pressure-accumulation vessel (12) to an nozzle hole (20f) for detecting pressure of fuel, the pressure sensor (20a) being located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12), the method comprising:

first-measuring a fluctuation in detected pressure mode of the pressure sensor (20a), the fluctuation appearing after an output of an injection instruction signal;
second-measuring an object fluctuation mode by conducting an examination for the fuel injection valve (20) and pressure sensor (20a) as examined objects of the malfunction; and
determining that the examined objects malfunction when an error of the object fluctuation mode with respect to a reference fluctuation mode as a reference is larger than a threshold.

15. A method for determining a malfunction caused in a fuel injection device, the fuel injection device including a fuel injection valve (20), which is configured to inject fuel distributed from a pressure-accumulation vessel (12), and a pressure sensor (20a), which is located in a fuel passage (25) extending from the pressure-accumulation vessel (12) to a nozzle hole (20f) for detecting pressure of fuel, the pressure sensor (20a) being located closer to the nozzle hole (20f) than the pressure-accumulation vessel (12), the method comprising:

first-measuring a reference fluctuation mode by conducting an examination for a master fuel injection valve (20m) and a master sensor (20am); and
second-measuring an object fluctuation mode by conducting an examination for the fuel injection valve (20) and pressure sensor (20a) as examined objects of the malfunction,

wherein each of the reference fluctuation mode and the object fluctuation mode represents a fluctuation in detected pressure subsequent to an output of an injection instruction signal, and
the master fuel injection valve (20m) and the master sensor (20am) are respectively different from the fuel injection valve (20) and pressure sensor (20a),
the method further comprising:

determining that at least one of the examined objects malfunctions when a deviation between the object fluctuation mode and the reference fluctuation mode is larger than a threshold.

FIG. 1

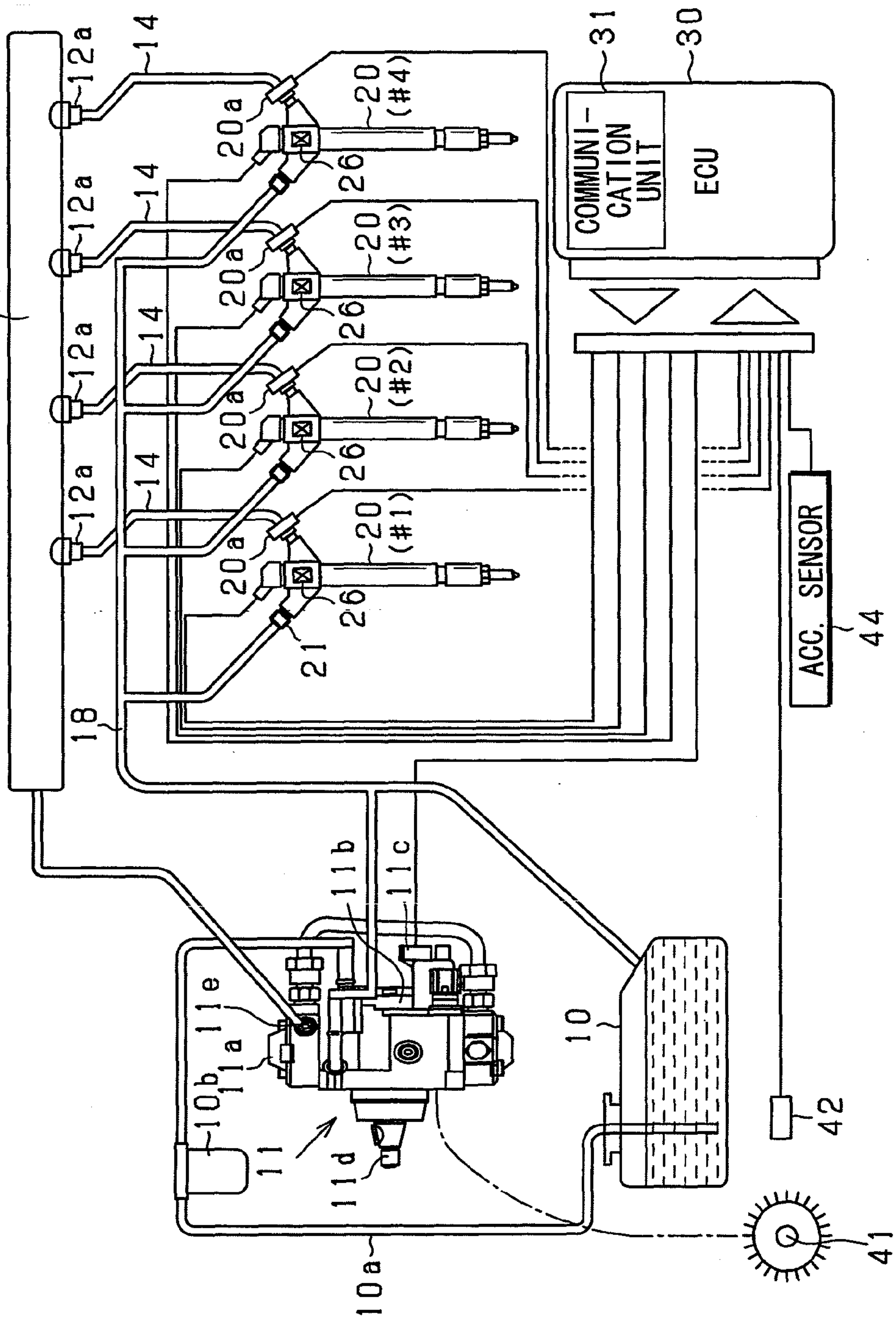

12
12a
12a
12a
12a
14
14
14
14
20a
20a
20a
20a
20 (#1)
20 (#2)
20 (#3)
20 (#4)
26
26
26
26
21
18
31
30
COMMUNI-
CATION
UNIT
ECU
ACC. SENSOR
44
11b
11c
11e
11a
10b
11
11d
10
10a
41
42

FIG. 2

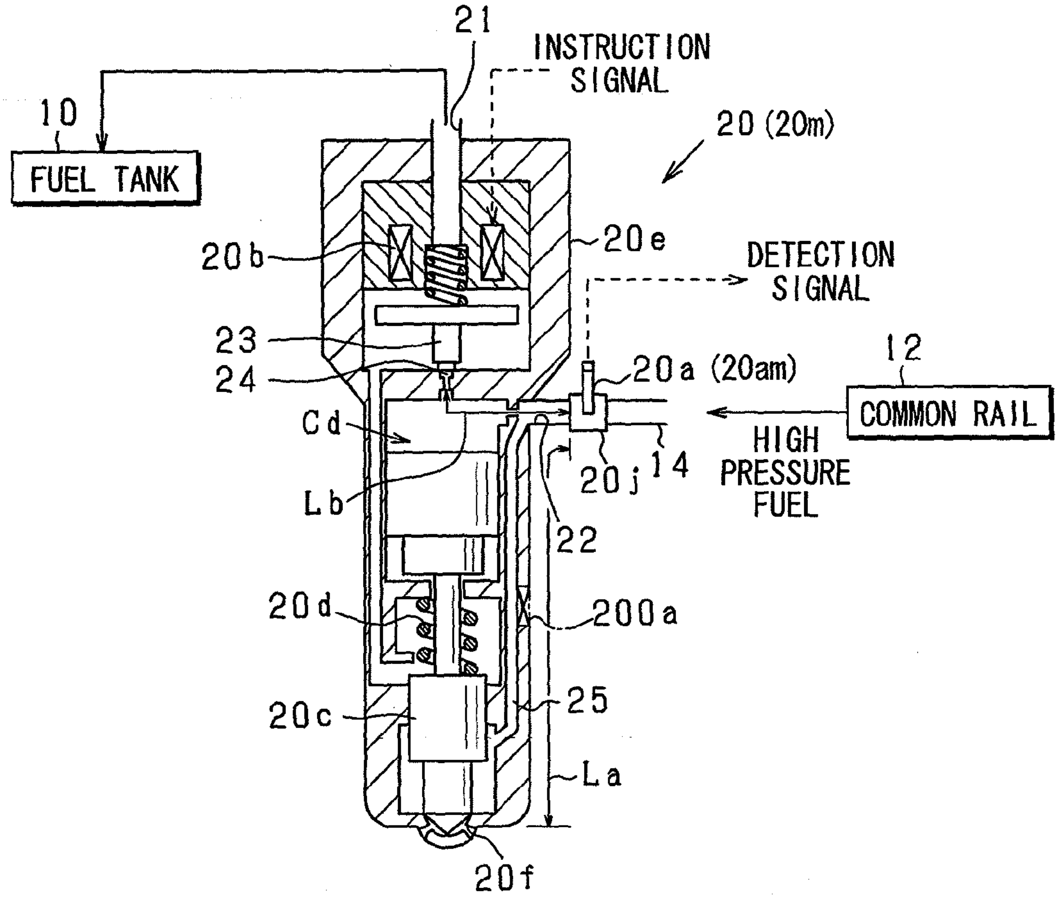

21
INSTRUCTION SIGNAL
10
FUEL TANK
20 (20m)
20b
20e
DETECTION SIGNAL
23
24
20a (20am)
12
COMMON RAIL
Cd
HIGH PRESSURE FUEL
Lb
20j
14
22
20d
200a
25
20c
La
20f

FIG. 3

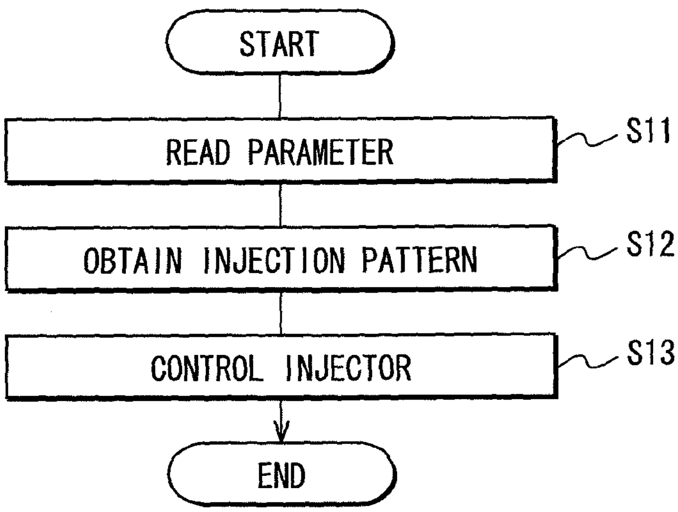

START
READ PARAMETER
S11
OBTAIN INJECTION PATTERN
S12
CONTROL INJECTOR
S13
END

FIG. 4

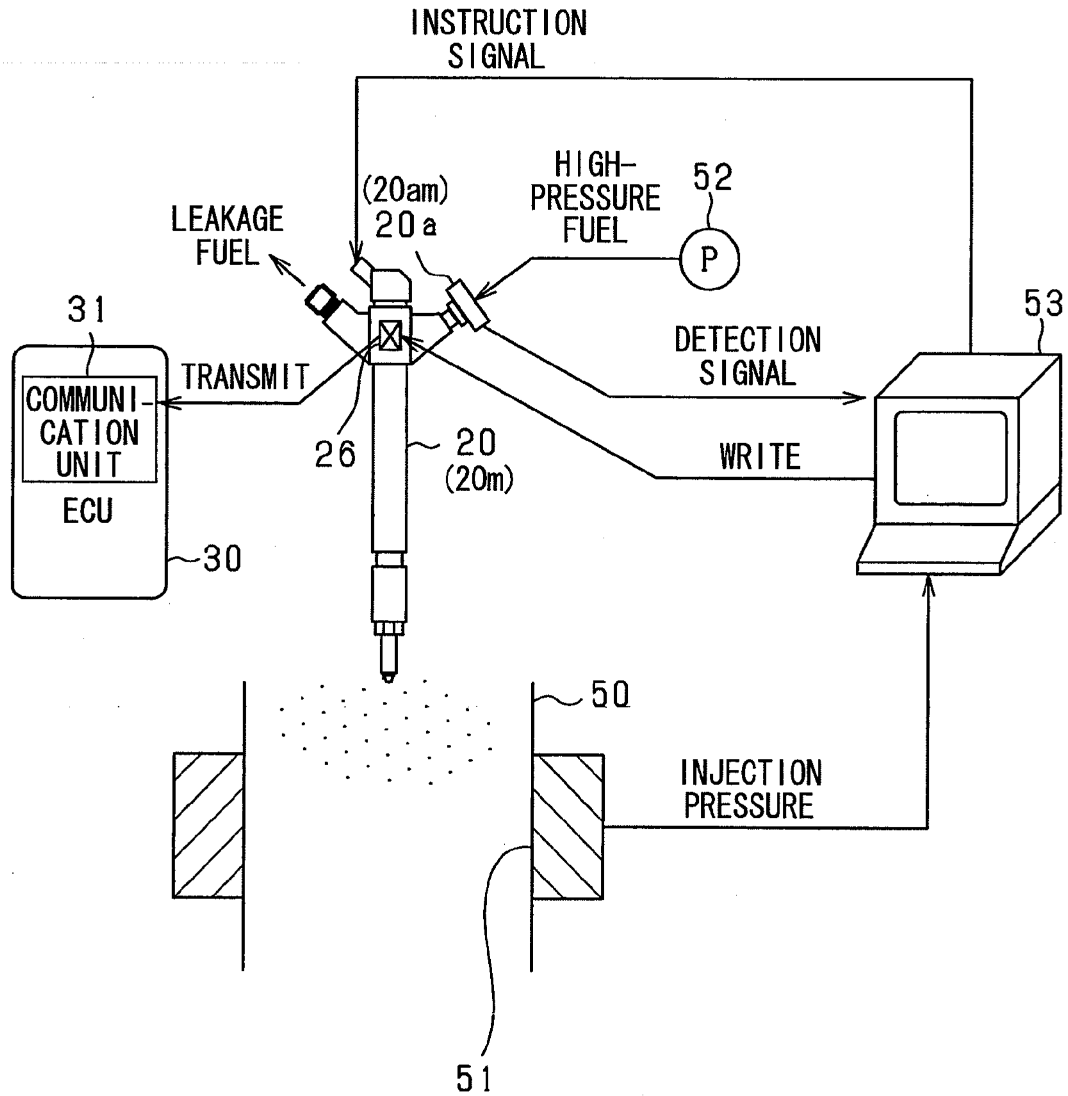
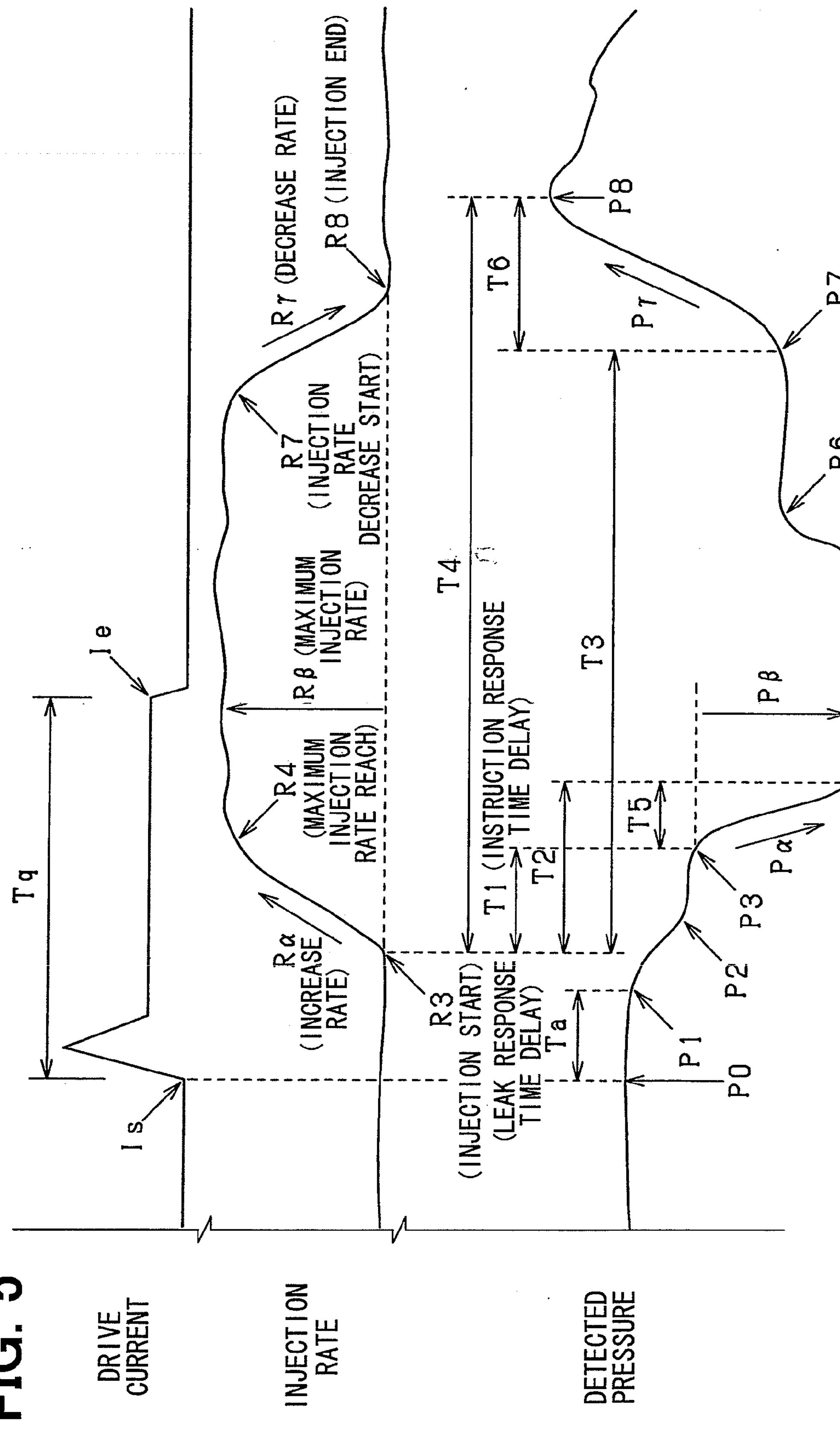

INSTRUCTION SIGNAL
(20am)
20a
HIGH-PRESSURE FUEL
52
P
LEAKAGE FUEL
31
53
DETECTION SIGNAL
TRANSMIT
COMMUNI-CATION UNIT
ECU
26
20
(20m)
WRITE
30
50
INJECTION PRESSURE
51

FIG. 5



DRIVE CURRENT
INJECTION RATE
DETECTED PRESSURE
Tq
Is
Ie
Rα (INCREASE RATE)
R3 (INJECTION START)
R4 (MAXIMUM INJECTION RATE REACH)
Rβ (MAXIMUM INJECTION RATE)
R7 (INJECTION RATE DECREASE START)
Rγ (DECREASE RATE)
R8 (INJECTION END)
(LEAK RESPONSE TIME DELAY) Ta
T1 (INSTRUCTION RESPONSE TIME DELAY)
T2
T3
T4
T5
T6
P0
P1
P2
P3
P4
P5
P6
P7
P8
Pα
Pβ
Pγ

FIG. 6

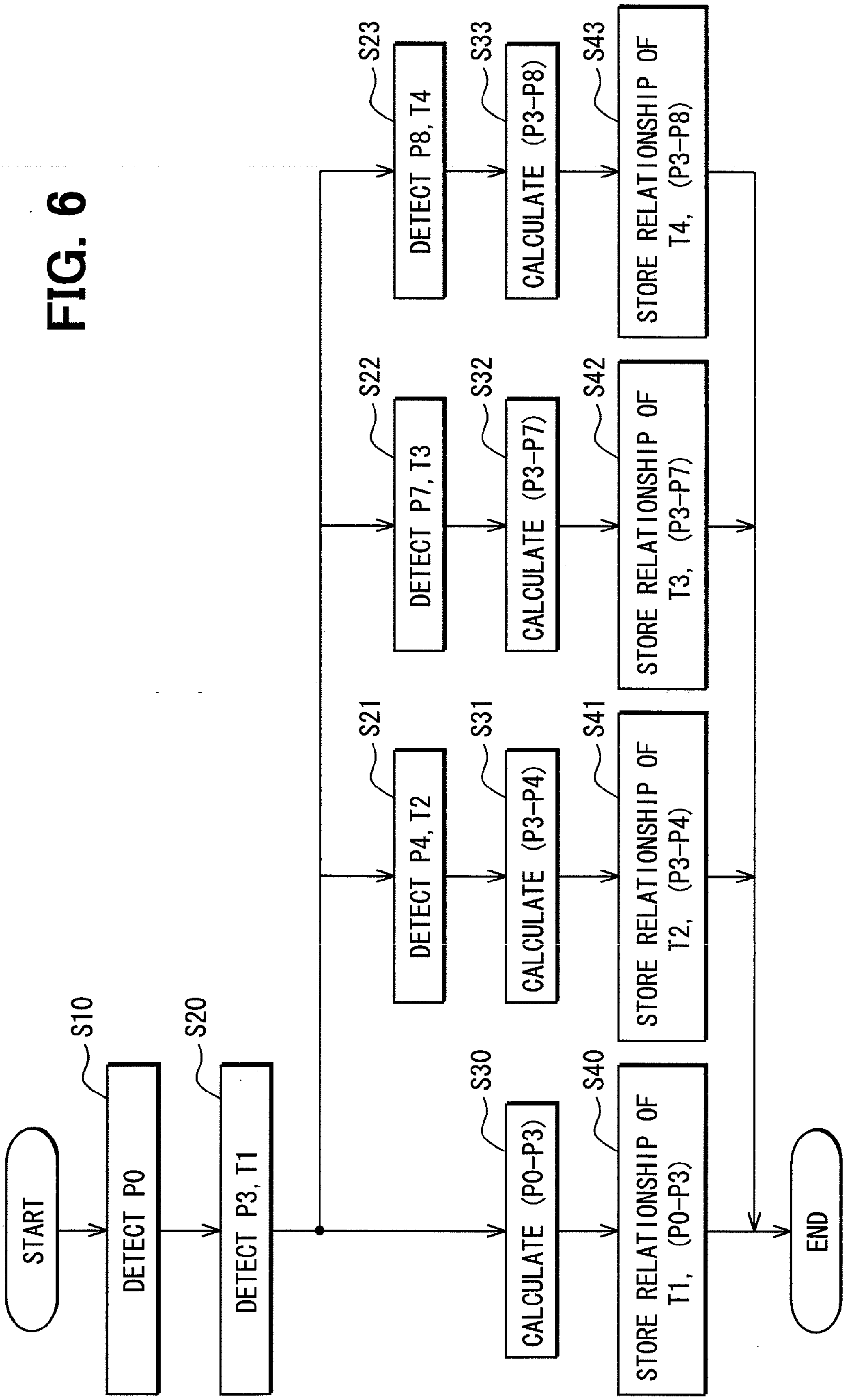

START
S10
DETECT P0
S20
DETECT P3, T1
S30
CALCULATE (P0−P3)
S40
STORE RELATIONSHIP OF T1, (P0−P3)
S21
DETECT P4, T2
S31
CALCULATE (P3−P4)
S41
STORE RELATIONSHIP OF T2, (P3−P4)
S22
DETECT P7, T3
S32
CALCULATE (P3−P7)
S42
STORE RELATIONSHIP OF T3, (P3−P7)
S23
DETECT P8, T4
S33
CALCULATE (P3−P8)
S43
STORE RELATIONSHIP OF T4, (P3−P8)
END

FIG. 7

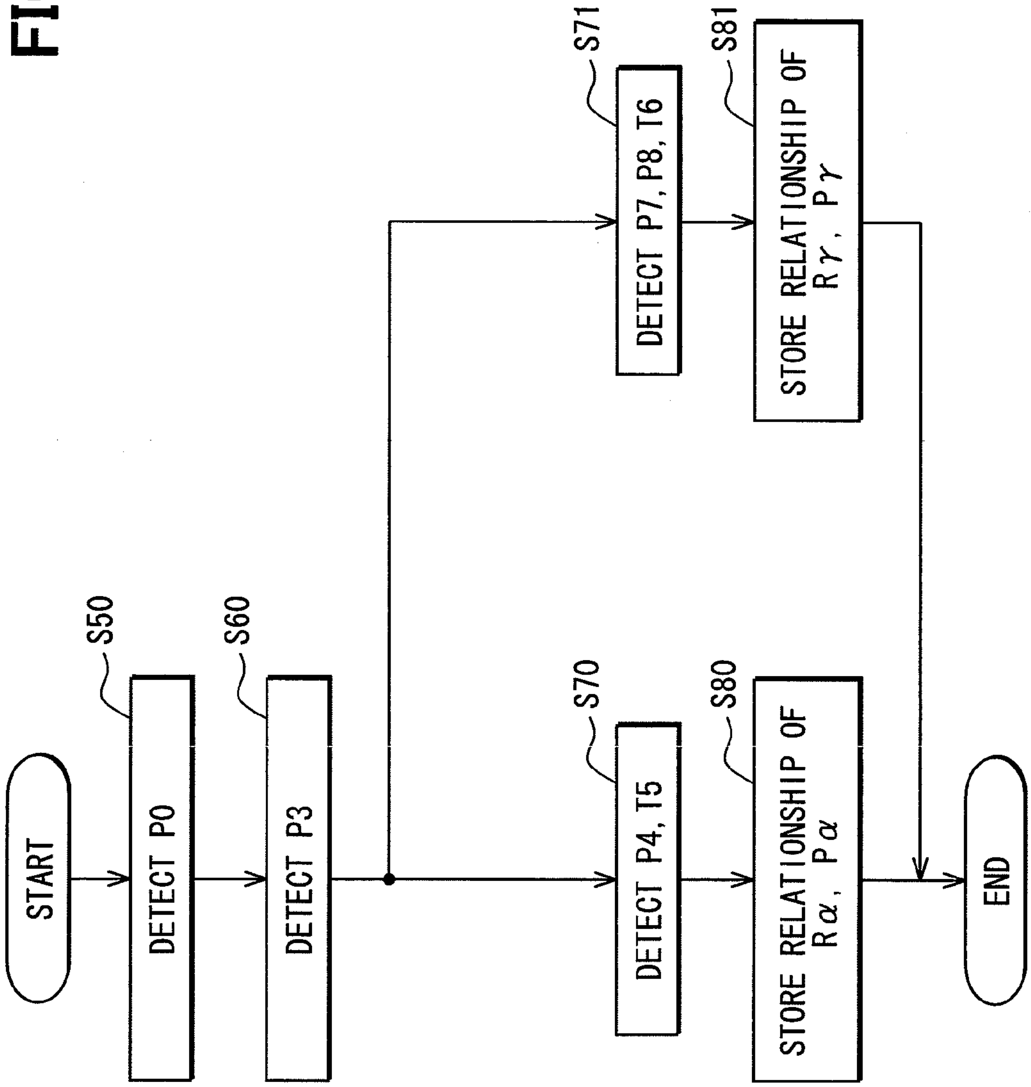

START
S50
DETECT P0
S60
DETECT P3
S70
DETECT P4, T5
S71
DETECT P7, P8, T6
S80
STORE RELATIONSHIP OF Rα, Pα
S81
STORE RELATIONSHIP OF Rγ, Pγ
END

FIG. 8

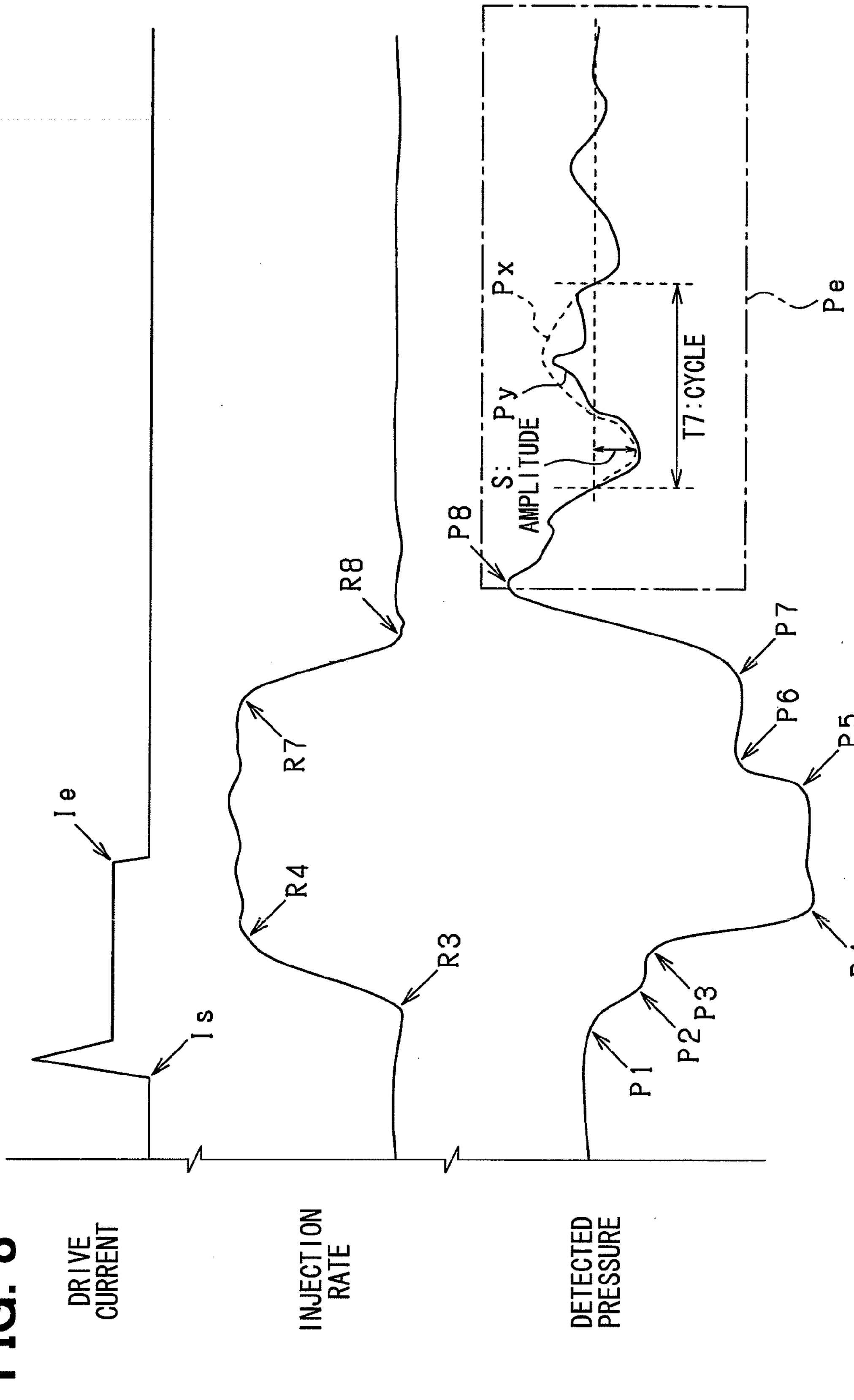

DRIVE CURRENT
INJECTION RATE
DETECTED PRESSURE
Is
Ie
R3
R4
R7
R8
P1
P2
P3
P4
P5
P6
P7
P8
S: AMPLITUDE
Py
Px
T7:CYCLE
Pe

FIG. 9

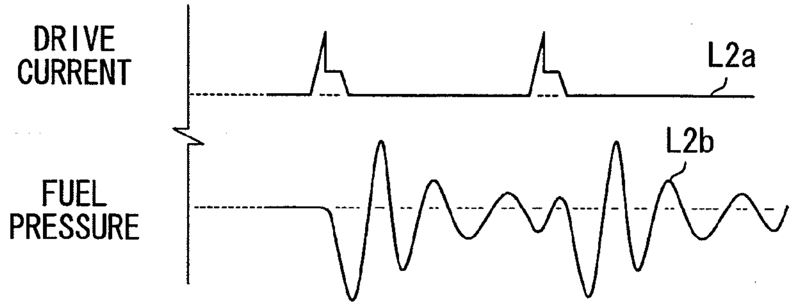


FIG. 10

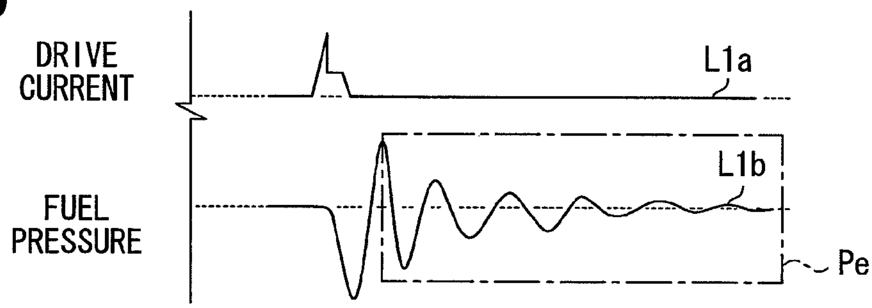


FIG. 11

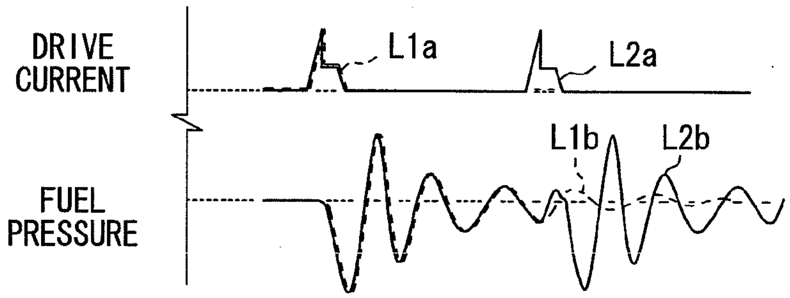


FIG. 12

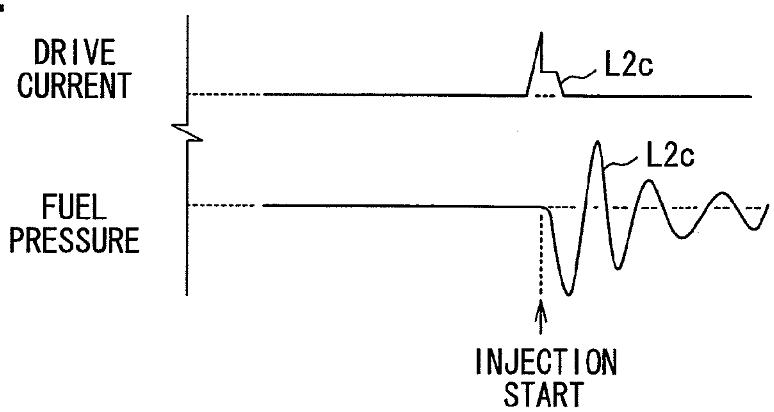


FIG. 13

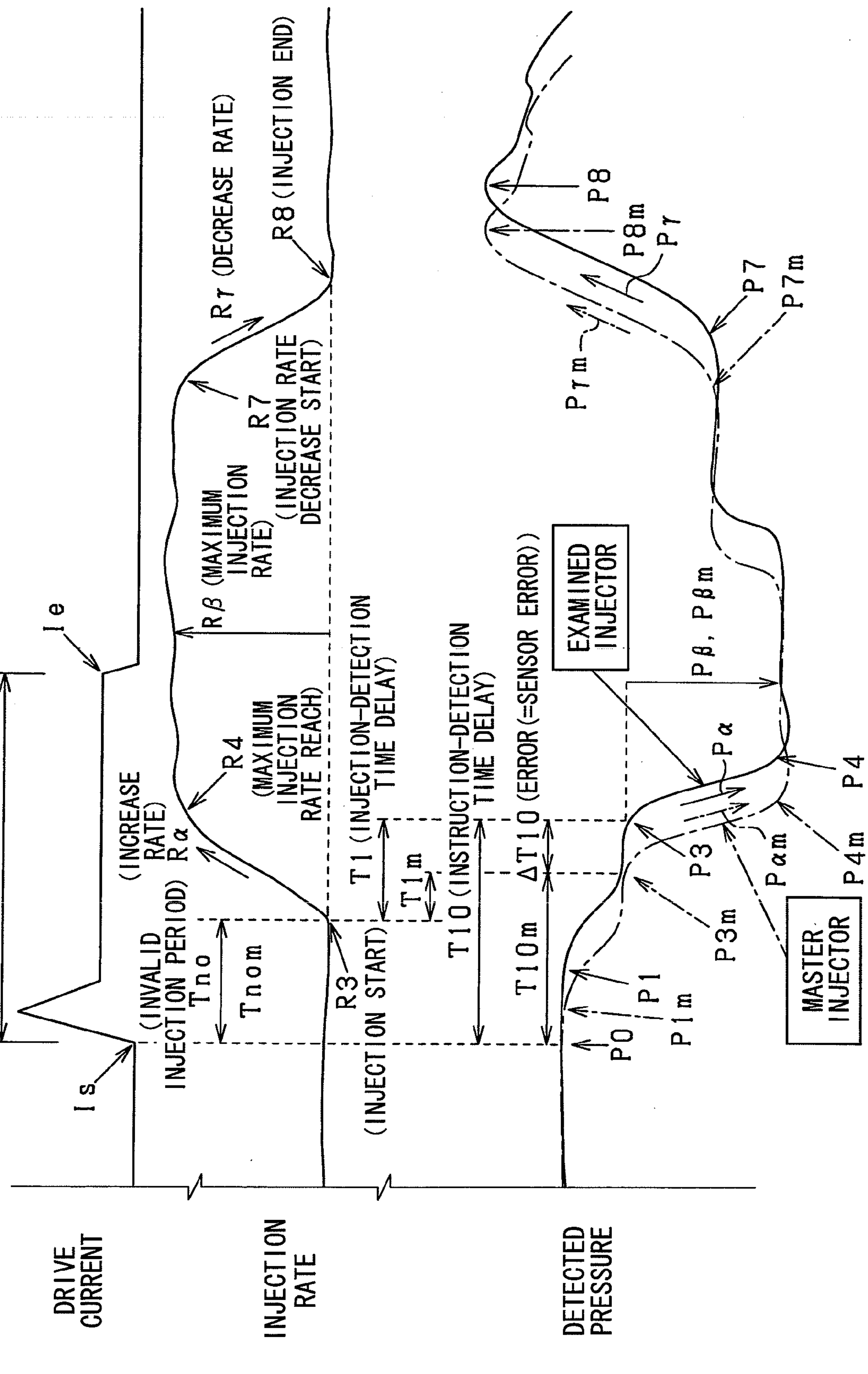

DRIVE CURRENT
INJECTION RATE
DETECTED PRESSURE
Is
Ie
Tq
(INVALID INJECTION PERIOD) Tno
Tnom
R3 (INJECTION START)
(INCREASE RATE) Rα
R4 (MAXIMUM INJECTION RATE REACH)
Rβ (MAXIMUM INJECTION RATE)
R7 (INJECTION RATE DECREASE START)
Rγ (DECREASE RATE)
R8 (INJECTION END)
T1 (INJECTION-DETECTION TIME DELAY)
T1m
T10 (INSTRUCTION-DETECTION TIME DELAY)
T10m
ΔT10 (ERROR (=SENSOR ERROR))
EXAMINED INJECTOR
MASTER INJECTOR
P0
P1
P1m
P3
P3m
Pα
Pαm
P4
P4m
Pβ, Pβm
P7
P7m
Pγ
Pγm
P8
P8m

FIG. 14

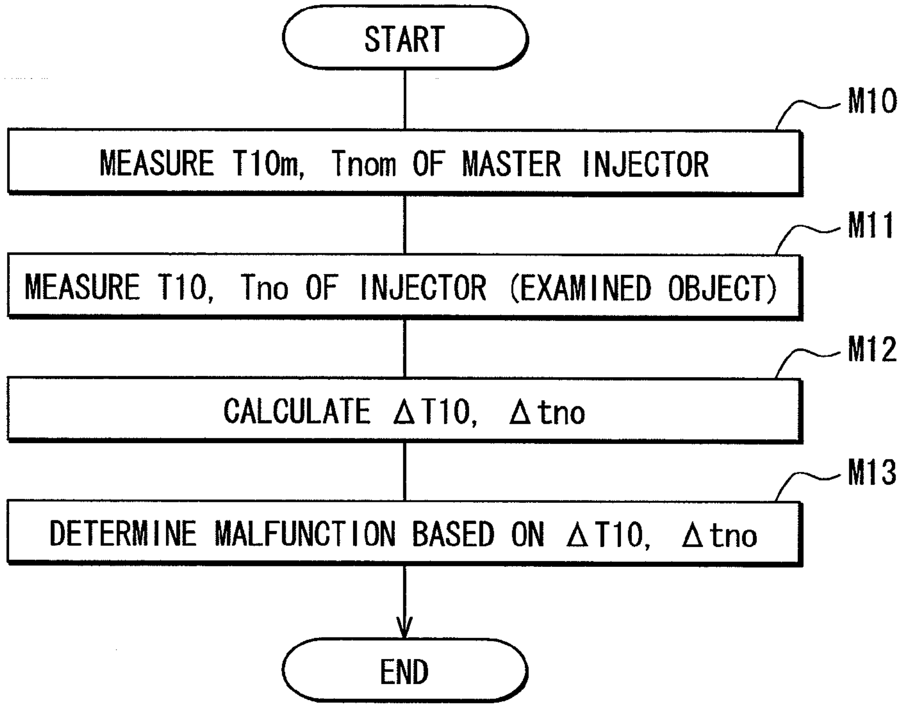
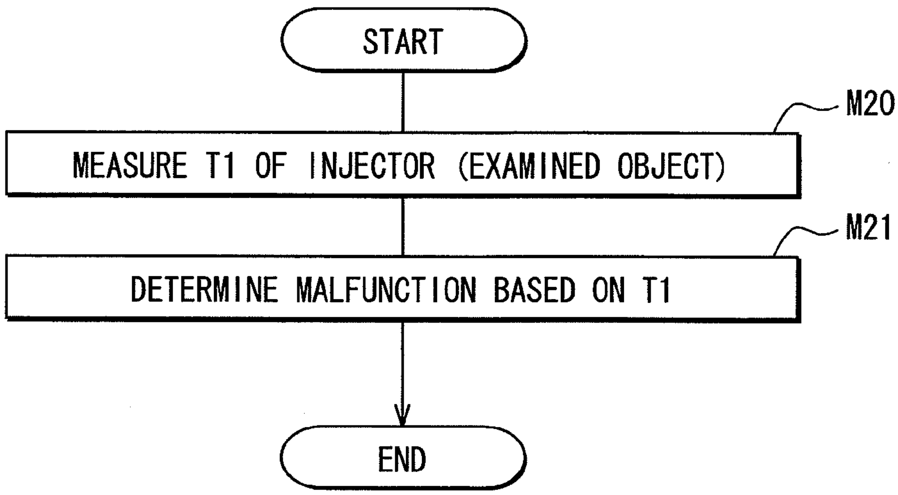

START
M10
MEASURE T10m, Tnom OF MASTER INJECTOR
M11
MEASURE T10, Tno OF INJECTOR (EXAMINED OBJECT)
M12
CALCULATE ΔT10, Δtno
M13
DETERMINE MALFUNCTION BASED ON ΔT10, Δtno
END

FIG. 15


START
M20
MEASURE T1 OF INJECTOR (EXAMINED OBJECT)
M21
DETERMINE MALFUNCTION BASED ON T1
END

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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